COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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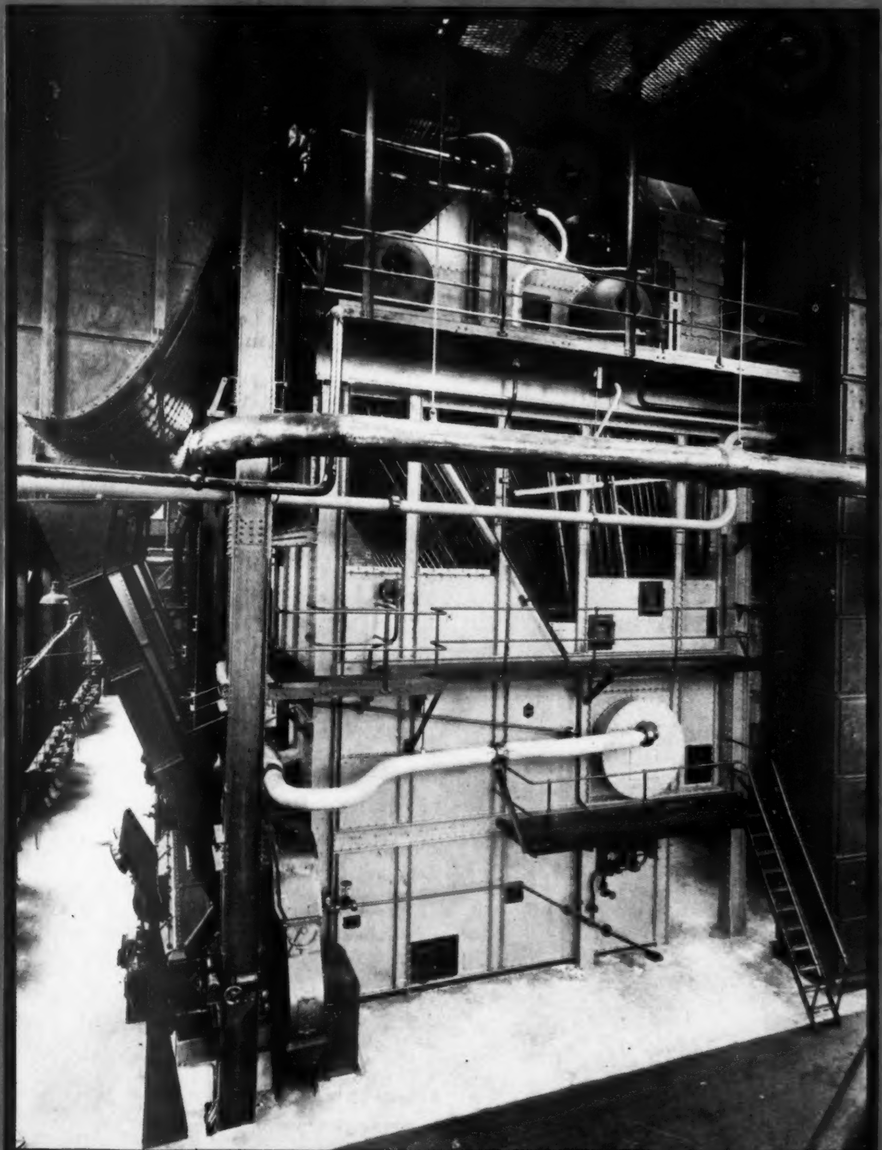

Photograph of boiler room of Dartford Paper Mills, England (*See model, page 22*)

Boiler Capacity Has Outgrown its Terminology

Models of Notable Power Plants of British Design

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VOLUME FIVE NUMBER NINE

CONTENTS

FOR MARCH 1934

FEATURE ARTICLES

EDITORIALS

DEPARTMENTS

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Editorial Announcement

For some months past, Alfred D. Blake has been serving *Combustion* in a consulting editorial capacity. With this issue, he assumes the responsibilities of Associate Editor, in which office he will have direct charge of the editorial content and arrangement of the magazine.

It is with much pleasure that we make this announcement to *Combustion's* readers, many of whom have known Mr. Blake in the many years he served as Managing Editor of *Power* and through his activities in the A.S.M.E. and other engineering societies. Mr. Blake's splendid qualifications as an editor and his long identification with the steam and power fields are assurances that *Combustion* will be ably edited and that its standards of technical journalism will be maintained.

In June of this year, *Combustion*, in its present form, will have completed five years of service to its field. During this period, as our new subtitle implies, the magazine has gained general recognition as a medium for presenting and interpreting the more important trends, practices and developments affecting the design and operation of steam plants. In performing this function comprehensively, and in sufficient technical detail to meet the requirements of engineers identified with steam plant work, we feel that *Combustion* has met a definite need and is filling a niche peculiarly its own.

The Editor wishes to take advantage of this opportunity to thank those engineers whose contributions have been so largely responsible for the prestige *Combustion* has attained, also the many readers whose helpful letters have aided in shaping the magazine's editorial policies and thus enabling it to render an increasingly constructive service to its field. Readers are invited to write Mr. Blake and extend suggestions or comments which will assist him in his task of editing the magazine to meet their needs.

Charles McDonough

Editor

"How are the tubes?"

"CLEAN as a whistle, chief. That Nalco System certainly is good. We can wash this boiler and put it right back on the line."

"THAT'S great. But with all the trouble we used to have I didn't feel right to let it go any longer without an inspection. They told me I could depend on those tests. Now I believe it."

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EDITORIAL

A Fair Weather Indication

The large number of active inquiries received by power equipment manufacturers since the first of the year and the substantial number of contracts already closed, indicates that industry has again turned to serious consideration of its power problems. This opinion is further strengthened by the fact that most of these are in no way traceable to public works aid, but have been initiated by industry itself. Furthermore, it is significant that these projects are not confined to a few industries but are spread over many lines.

Just as many of us have discovered that there is a limit to the mending and pressing of the old suit, so have managements come to realize that they must modernize or replace much of their power equipment if they are to be in a strong position to compete in the recovery that has already set in.

With the index of industrial activity advanced to sixty-six per cent of normal, and in many lines much higher; with the central-station load consistently increasing week by week; and with the monetary situation now definitely charted, there is strong basis for the belief that the next six months will be a period of accelerated activity for all phases of the steam and power fields.

Be Sure of Your Boilers

Twenty years ago boiler explosions were frequent, and their destructive effects provided many headlines for local papers as well as numerous analytical discussions in the technical press. In some years the number of explosions ran from three to four hundred with considerable loss of life, personal injury and vast property damage.

With improvements in boiler design and materials, closer attention to feedwater treatment, education of the operators and the extension of license legislation, the number and seriousness of these explosions greatly diminished, despite a rapid expansion in steam-generating capacity throughout the country. In fact, explosions of a major character became a rarity. A large share of the credit for this improvement is due the A.S.M.E. Boiler Code and the work of the American Uniform Boiler Law Society in fostering legislation embodying the provisions of the Code.

It is therefore surprising to read in the last issue of *The Locomotive* that recent months have seen a number of serious explosions of stationary power boilers, which have taken a toll of sixteen lives, injured many people and been accompanied by large property damage. However, it is significant that practically all were in the relatively low-pressure class and several in seasonal service.

Obviously, boiler explosions never have been, and probably never will be, entirely eliminated. The shortcomings of human nature will always be with us. That a number of disastrous explosions should have occurred recently may be merely a coincidence; yet it is conceivable that conditions obtaining during the past two years have led to measures of false economy that were directly or indirectly responsible. The laying up of boilers without proper precautions against corrosion, deferred maintenance, makeshift repairs, lack of intelligent inspection and the use of boilers beyond their useful life are all contributing factors to conditions that invite failure and possible disaster.

With production now becoming active, it is important that boilers be looked over carefully by competent men, that all necessary repairs be properly made and, where any doubt exists as to safety, that replacements be made. Industry cannot afford any semblance of a recurrence of the conditions of twenty years ago. Laxity of supervision must not be permitted to combat the results of engineering talent applied over the intervening years.

Let the cases which are cited by *The Locomotive* serve as a warning.

Trends in Power Plant Design

There is an old adage that "One swallow doesn't make a spring." This logic may well be applied at present to assumed trends in power plant design. The dearth of new construction during the past two years makes it advisable that we do not regard designs of the few plants built as indicating definite trends, as some appear to have done. These installations may be considered as embodying the views of their respective designers rather than representing a consensus of engineering opinion in the field.

Furthermore, it should be remembered that these installations were made in a period of unparalleled economic stress, with labor and material prices at low levels, and loads far from normal, all of which are likely to exert an influence on the general design. It is conceivable that conditions may have so changed within the next year or two as to warrant quite different treatment.

Trends in power plant design should not be confused with progress in the design of individual equipment that makes for better efficiency, greater reliability and lessened maintenance; nor with the results of research as applied to materials and the solution of special problems. These may be definitely recognized and evaluated, whereas trends, as represented by the selection of operating conditions, sizes of units, types and combinations of equipment that go to make up the complete plant, must be predicated upon adequate supporting evidence, properly interpreted.

Boiler Capacity has Outgrown its Terminology

By OTTO de LORENZI
Combustion Engineering Company, Inc., New York

The purchaser of a steam-generator is concerned only with its ability to deliver a given amount of steam, economically, at a predetermined pressure and temperature and given exit gas temperature. He is not concerned with the amount or distribution of the surface and builder's rating has no significance. The author has compiled and plotted certain design data from fifty-two installations, covering both straight-tube and bent-tube boilers, and shows that, without reference to heating surface, the maximum dry steam liberation at various pressures follows a definite law.

TODAY many boiler specifications are written in the same manner as they were by our grandfathers, notwithstanding the fact that engineering design has advanced far beyond their older arbitrary definitions. Too often the following clauses appear, "a boiler horsepower shall be defined as ten square feet of water-touched and gas-swept surface," and, "the boiler shall be operated at blank per cent of builder's rating." Obviously, an arbitrary standard is here set up. This standard does not take into account many of the increments in design, which makes one boiler differ radically from another in the amount of steam it is capable of generating, even though it may contain the same amount of heating surface.

The prospective boiler purchaser should not be primarily interested in purchasing a definite number of square feet of water-heating surface. He should be interested in purchasing, economically, a steam generating unit which is capable of delivering, continuously, a definite amount of steam output, at a predetermined pressure and temperature, and at a stated boiler exit gas temperature.

Whether the steam is to be dry saturated or superheated does not matter particularly. In either case the steam to the main header or superheater inlet must be commercially dry and relatively free from impurities, so that no detrimental accumulation of solids will occur in any part of the system.

During the past fifteen or twenty years, boiler outputs, based on per cent of builder's rating, have been steadily mounting. Today it is not uncommon to read of units operating satisfactorily at five hundred or even one thousand per cent of rating.

Prior to 1920, where coal was the fuel burned, boilers were either hand- or stoker-fired. In the case of chain-grate stokers, when burning bituminous coal, the design was for natural-draft operation. The combustion rate per square foot of grate surface rarely exceeded thirty-five pounds. In the installations using anthracite as fuel, the forced-draft traveling grate proved to be the only practical stoker. The average combustion rates with this fuel were rarely greater than thirty pounds per square foot. Where the underfeed stoker was used it was either of the single center-retort type or of the conventional multiple-retort type. The combustion rates of these types of machines were usually less than forty pounds per square foot.

Oil-fired installations were, in practically all cases provided with natural-draft types of burners of various designs. Air, steam and mechanical atomization were used to secure effective division of the fuel into a sufficiently fine spray or mist, so that combustion was completed with not too great percentages of excess air.

Gas-fired installations were principally of the low-pressure type, i.e., the gas burners received the fuel at pressures measured in ounces instead of pounds. As a consequence, a multiplicity of relatively lazy gas streams entered the furnace and slowly mixed with the air for combustion.

The boilers themselves were generally set low. A setting height of fourteen feet under the high header, in the case of the straight-tube boiler, or one of five feet to the center line of the mud drum, in the case of the bent-tube boiler, was the exception rather than the rule. Consequently the furnace volume available was limited.

With the first pulverized-fuel-fired installation, in a central station, came many experiments to determine the best type of furnace design to secure continuity of service. Many careful tests were conducted and from these data definite relations were established between capacity, efficiency and heat liberation in the furnace. With these data as a basis, a new station was designed and completely equipped for pulverized-fuel firing. The results obtained proved conclusively the soundness of this method of fuel burning and also laid the foundation for our present-day high capacity units.

Realizing that pulverized-fuel firing would prove to be a real competitor, stoker engineers began to test and redesign their equipment in an effort to improve performance. Combustion rates, per square foot of grate surface, steadily climbed. Boilers were set higher to secure adequate furnace volume. The race was on in an effort to see just how much fuel could be burned per foot of furnace width.

The apparent maximum was reached, when increasing maintenance and too frequent boiler outage indicated

that it was economically unsound to go further in this race. However, just at this time, the water-cooled metallic furnace wall was developed and immediately proved its value. Because this type of wall is not damaged by flame impingement, it is possible to utilize all of the combustion space provided. Fuel and air velocities were stepped up, resulting in intense turbulence in the furnace. The time required to complete combustion was reduced, because of the more rapid and intimate mixing of the air and fuel, and liberation rates reached a new "high."

Oil and gas firing kept pace with coal firing. Forced-draft burners provided the rapid mixing of fuel and air and produced violent turbulence. Liberation rates were stepped up and, at the same time, the amount of excess air, required to complete combustion, was reduced. The water-cooled furnace lining was a further aid. It was possible to reduce the furnace draft to practically a balanced condition, and yet prevent the furnace linings from being damaged by the high temperatures which exist under these conditions.

To meet the demands imposed by the rapid strides made in furnace and fuel-burning equipment designs it became necessary to modify the boilers.

The earlier boilers usually had a relatively small amount of heating surface per foot of furnace width. The drum centers of the bent-tube types were relatively low. In the straight-tube types the distance between headers was short. As the amount of fuel burned per foot of furnace width increased, the amount of heat available to each boiler section was greater. If the surface for absorbing this heat is not sufficiently large, low efficiency will result due to high exit gas temperatures. Furthermore, because larger gas quantities must pass through the boiler, high draft loss will occur, unless the various passes are opened up. The first steps in design were to crowd as much surface as possible into a given width and, at the same time, increase tube lengths, so that the gas passages would be longer and less restricted. Feedwater economizers were used to convert much of the otherwise wasted heat into useful work.

About this time operating pressures and temperatures began to climb. The heating of feedwater by bleeding steam from the turbine, came into general use. Air heaters, to a great extent, replaced economizers.

The overall operating efficiency, in many units, exceeded eighty-five per cent, even though so-called ratings were greater than four hundred per cent. In some cases, however, trouble developed. Considerable moisture was being carried over with the steam into the superheater. Deposits of solids in turbine stages made necessary periodic washing or shutting down for cleaning. To remedy this condition the feedwater was dosed with chemicals and "patent medicine" compounds. Results were encouraging in some instances, while in others the conditions were aggravated. Similar units in different plants did not perform the same. The maximum rating on one was lower than that attainable on the other. Changes were made in steam circulators. Internal baffling was rearranged. In some instances conditions were improved; in others it was necessary to accept the reduced output.

We now enter a period in which real strides were made in improving boiler design. Circulation received serious consideration. Rearrangements of tube banks were made so that positive and more rapid circulation was assured. The steam and water circuits were more uniformly balanced. The steam generated, where possible, was delivered close to or even above the water line in the drums. The steam itself was more uniformly distributed in the steam space to prevent the starving of one drum while another was overloaded. Scientific methods of controlled feedwater treatment were developed and applied to reduce the presence of undesirable suspended or dissolved solids. The continuous blowdown was used to maintain the concentration of solids in the boiler below the danger point. Engineers began to speak of the output of a unit in terms of pounds of steam instead of ratings. Many specifications were now being drawn, in which the amount and distribution of surface to be provided in a steam-generating unit, to give a stated output at a given efficiency or exit gas temperature, was left to the judgment and experience of the boiler manufacturer. The use of the term "per cent of rating" became less and less. What should be substituted in its place? Is there a definite "yardstick" or "common denominator" available? Yes, as there is a large amount of factual data, which strongly indicates the apparent limitations applying to the two broad boiler classifications—the bent-tube and the straight-tube types. With these data it is possible to predict, very closely, the maximum output of any given unit. It is this maximum output in which we are interested and, therefore, it should be the rated capacity of the unit.

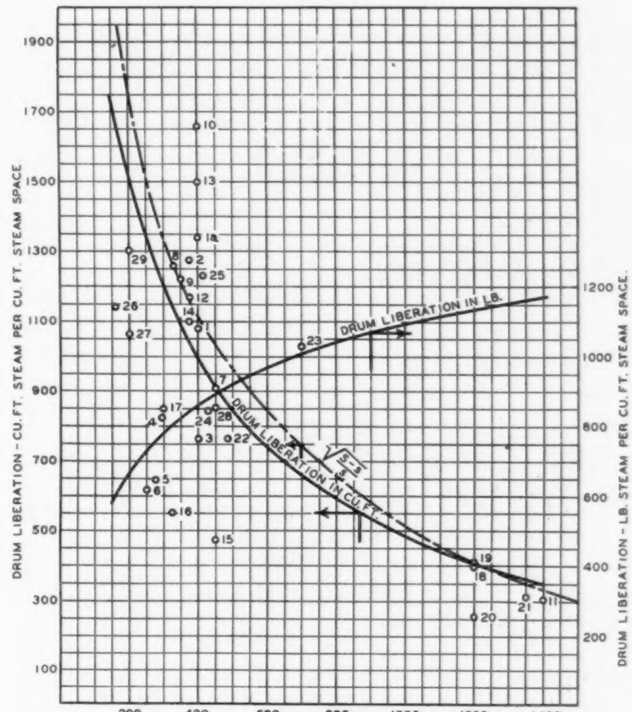

Fig. 1—Data plotted from Table I for straight-tube boilers showing drum liberation in cubic feet and pounds

A turbine unit is rated in terms of its maximum capacity. It is only logical that a steam-generating unit should be rated in the same manner. When purchasing a turbine we are not particularly interested in the number of buckets per stage nor even the number of stages. We are, however, intensely interested in the maximum kilowatt output at a given water rate, when

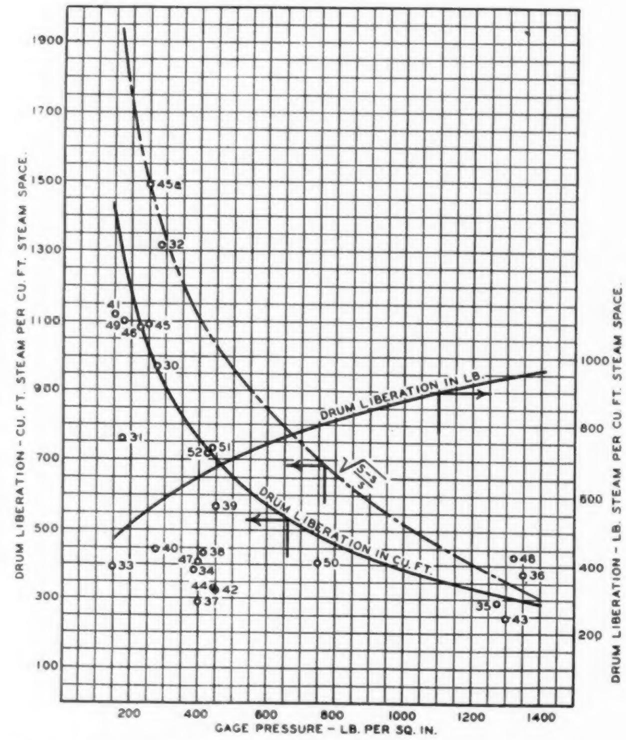

Fig. 2—Data plotted from Table II for bent-tube boilers showing drum liberation in cubic feet and pounds

the turbine is supplied with steam at a stated throttle pressure and temperature, and operated with a definite back pressure.

In purchasing a steam generating unit, the factors of prime importance, then, are the maximum steam output at a definite pressure and quality or temperature, and secured at an efficiency that is economically justified. The individual sizes of the boiler, economizer, air heater and other auxiliary equipment is of little importance to the purchaser, except as they, in their entirety, affect the installed cost of the unit.

In steam-generating units we find that up to a certain output the steam is commercially dry. If this output is exceeded, the moisture content will increase rapidly. The maximum point at which dry steam is obtainable is a function of drum pressure, steam space in the boiler drums, character of feedwater and type of boiler. To visualize more clearly the foregoing statements, operating and design data have been compiled from fifty-two plants. These data are shown in Tables I and II.

Table I contains data pertaining to the cross-drum, straight-tube type of boiler, of both sectional and box-header construction. The range in pressures, is from 160 lb per sq in. to 1400 lb per sq in. The steam space is calculated as the entire drum volume above the normal water line. In the cases where the boiler design involves more than one drum, the total steam space in all drums is used. The drum liberation, in cubic feet of steam per cubic foot of drum volume, is obtained from the maximum output at which the particular unit has been operated. Notes are also included to give the steam conditions, so that they may assist in arriving at the conclusions, which are drawn from these data.

Table II contains data pertaining to the bent-tube type of boiler. Included are two-, three- and four-drum types, with and without dry drums. Where dry drums are used, the calculated steam space includes the entire volume of the dry drums. The range in pressure is from 150 lb per sq in. to 1350 lb per sq in. Here again the drum liberation is based on the maximum output at which these units have been operated. Comments as to steam conditions are also included.

By plotting these data, for the straight-tube boiler as revealed in Table I, it is possible to assign definite values for the maximum steam liberation rates at various pressures. Fig. 1 graphically portrays these data. Each point plotted carries a number which corresponds to the plant number in the table, and therefore makes identification easy. It will be immediately noted that the dispersion is apparently quite wide. A large scale however, has been purposely selected to assist in reading the values. To draw a truly representative curve it is necessary to discard certain points, because "wet" steam conditions are indicated in the tabulation. All of these points, however, lie well above others, at the same pressure, in which "dry" steam was obtained.

Plant 1 is of special interest because we have in the first instance dry steam. Then as the liberation is increased wet steam results. This latter condition is indicated by plant 1a.

Having discarded the definitely "wet" steamers, it is now necessary to arrive at some average values for actually plotting the curve. This is relatively easy in the range between 250 and 500 lb per sq in. and between 1200 and 1400 lb per sq in. There is only one point which lies in the region between 500 and 1200 lb per sq in. This particular installation differs from all the others, in that it is provided with special experimental baffling. This baffling has made it possible to produce dry steam at the high liberation rate tabulated. This point will, therefore, influence the curve, but, inasmuch as this is a special case, it is indicative of future developments rather than the practice represented in existing installations. At 1200 lb we have two points which practically coincide so it is assumed that the curve should pass through them. Plant 7, at 450 lb has dry steam and is therefore used as another anchor for the

TABLE I—DESIGN AND OPERATING DATA ON CROSS-DRUM, STRAIGHT-TUBE BOILERS

Plant	Type of Boiler	Steam Press.	Drum Liberation Cu Ft Steam Per Cu Ft St. Space	Cond. Steam
1	A	400	1080	OK
1a	A	400	1340	Wet
2	A	375	1275	Wet
3	B	400	765	OK
4	B	295	827	OK
5	C	275	647	OK
6	A	250	618	OK
7	A	450	910	OK
8	A	330	1260	OK
9	A	350	1220	OK
10	A	400	1660	Wet
11	A	1400	306	OK
12	A	375	1170	OK
13	A	400	1500	Wet
14	A	375	1100	OK
15	A	450	472	OK
16	A	325	552	OK
17	A	300	850	OK
18	A	1200	400	OK
19	A	1200	409	OK
20	A	1200	257	OK
21	A	1350	312	OK
22	A	488	765	OK
23	A	700	1030	OK*
24	A	430	842	OK
25	A	415	1230	Wet
26	B	160	1140	OK
27	A	200	1065	OK
28	A	450	852	OK
29	A	200	1302	OK

* Special baffling in this boiler.

A Cross-drum sectional-header boiler.
B Cross-drum box-header boiler.
C Multi-drum straight-tube boiler.

TABLE II—DESIGN AND OPERATING DATA ON BENT-TUBE BOILERS

Plant	Type of Boiler	Steam Press.	Drum Liberation Cu Ft Steam Per Cu Ft St. Space	Cond. Steam
30	F	275	970	OK
31	D	175	760	OK
32	E	285	1315	Wet
33	D	150	390	OK
34	D	383	383	OK
35	F	1275	288	OK
36	E	1350	378	OK
37	D	400	289	OK
38	D	415	433	OK
39	D	450	570	OK
40	D	275	445	OK
41	D	150	1120	OK
42	D	450	321	OK
43	F	1300	241	OK
44	D	445	327	OK
45	E	250	990	OK
45a	E	250	1490	Wet
46	E	225	1080	OK
47	F	400	407	OK
48	F	1325	426	OK
49	D	180	1100	OK
50	E	750	404	OK
51	F	440	730	OK
52	D	425	718	OK

D Four-drum bent-tube boiler.
E Two-drum bent-tube boiler with and without dry drum.
F Three-drum bent-tube boiler with and without dry drum.

curve. Between 300 and 400 lb there are several high points and also a few low ones. Furthermore, between 160 and 300 lb there are three relatively low points, which will pull the curve downward to the position in which it has been drawn.

From the curve described, it is now possible to construct a second one to give readings of drum liberation in pounds per cubic foot of drum space at the various pressures. This curve is of more practical value as the capacity of a unit is invariably stated in pounds, rather than cubic feet of steam.

Fig. 2 graphically portrays the data for bent-tube types of boilers shown in Table II. Here again each plotted point carries the corresponding number of the plant it represents. Two of these points, plants 32 and 45a, are discarded as the steam conditions are definitely listed as "wet."

In the case of plant 45 we again have two points, 45a, which is definitely listed as "wet," and 45 which is dry.

A number of the other plants are dry, but lie in the very low zone of liberation. The steam conditions in all of these cases is dry but apparently, for one reason or another, no attempt has been made to determine just how high the units may be forced before excessive moisture is carried over.

In this group of data we have a number of well spaced maximum points, over the pressure range, in which favorable operating conditions were obtained. These points are used as anchors and the curve drawn through them. A second curve has again been constructed to give direct readings of drum liberation in pounds per cubic foot at the various pressures.

In column four of Tables I and II, drum liberation in cubic feet of steam per cubic foot of steam space, we have a comparison common to all types of boilers. These values are a relative measure of the time, and therefore the velocity, for settling out the moisture from the steam. The moisture may be assumed to be solid particles falling in a fluid, steam. The particles are not microscopic in size and their velocity will therefore follow the law:

$$V = KD^{1/2}\sqrt{\frac{S-s}{s}} \quad *$$

where, D = diameter of particle
S = pounds per cubic foot, boiler water
s = pounds per cubic foot, steam
K = constant = 9.3 in formula

The curve, as represented by this formula, has been plotted in both Figs. 1 and 2. In the case of Fig. 1, the points 8, 9, 12, 14 and 1 have been used to locate this curve. The reason for this selection is that here we have the most compact grouping of data, and extending the curve to either higher or lower pressures is simply a matter of following the formula. The curve as plotted in Fig. 2 carries the same values as it has in Fig. 1, and thus gives a direct comparison between the bent-tube and the straight-tube types of boilers.

In the case of Fig. 1, an inspection discloses that the settling velocity curve lies close to the maximum liberation curve, and practically parallels it throughout the entire range. This velocity is then indicative of the maximum liberation at which dry steam may be expected in a straight-tube type of boiler. The zone between the two curves may be assumed to be one of uncertainty, wherein difficulty may be encountered if all conditions are not just correct.

In the case of Fig. 2, the settling velocity curve lies further away from the liberation curve. However, they are again practically parallel. The zone of uncertainty is therefore greater than with the straight-tube boiler.

* Walker, Lewis & McAdams, *Principles of Chemical Engineering*, page 310.

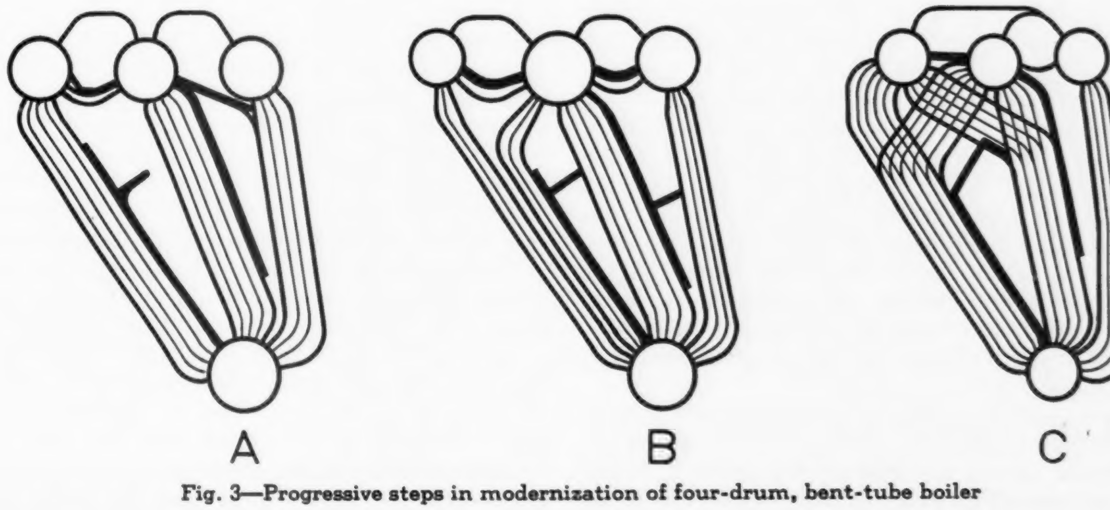

Fig. 3—Progressive steps in modernization of four-drum, bent-tube boiler

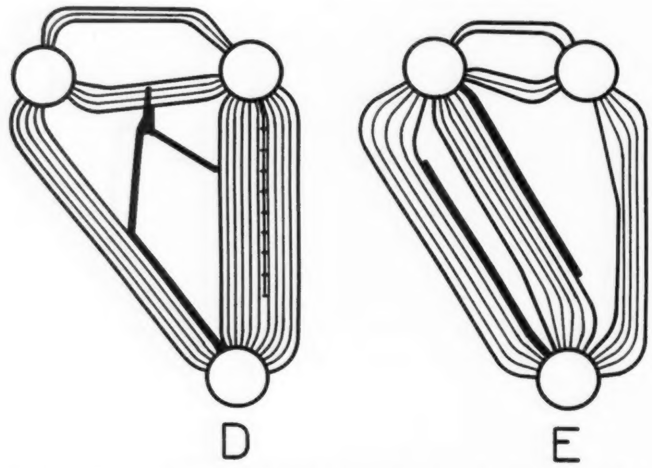

Fig. 4—Two stages in three-drum, bent-tube boiler design

This variation is probably due to design and circulation differences. It may be explained by the fact that in the straight-tube type of boiler considerable recirculation takes place in the upper part of the boiler bank. Therefore, the velocity of steam and water through the upper circulators and into the drum is relatively low. The mixture is therefore projected into the drum, at or above the water line, at relatively low velocities, and hence will entrain less moisture.

In the four-drum, bent-tube type of boiler, the circulation is quite different. All of the steam and water in the first tube bank, in practically all designs, passes into the upper front drum. Because all of these tubes lie below the center line of the drum, the steam frees itself from the water in gulps, causing violent ebullition. The result is that the steam, as it passes into the upper circulators, carries a high percentage of moisture over into the second, or middle drum. To unload the first drum, water circulators are provided. The steam generated in the second tube bank discharges below the water line, into the second drum. The steam from the two front drums is now taken, through another series of circulators, into the rear drum. It is in this last drum that the moisture must be settled out if dry steam is to be obtained from the unit. Obviously, this serial circulation of the steam offers less opportunity for removing the moisture and therefore more total volume must be provided, for a given output, than is required by the straight-tube boiler.

By a rearrangement of the steam and water circuits in the bent-tube boiler it is possible to balance the liberation in the two front drums. This is best accomplished by equally dividing and then connecting the first and second tube banks to the two front drums. By doing this, the amount of steam liberated in these drums is the same. Steam circulators are then provided to connect each drum directly to the rear drum. Because of reduced ebullition, the amount of moisture carried by the steam, as it enters the rear drum, is materially reduced. Drying can therefore be more effectively carried out, and the permissible liberation will approach that of the straight-tube boiler very closely.

The progressive steps in the modernization of the four-drum, bent-tube boiler are well illustrated in Fig 3. Three different boilers are shown. The first, A, is the conventional four-drum type, in which all of the tubes in the front bank enter the upper front drum. All of the tubes of the second bank enter the middle drum. The tubes of the rear bank with the exception of the first row, enter the rear drum. Steam circulators are provided between the first and middle, and between the middle and rear drums. Water circulators also connect the front and middle drum. No water circulators are provided between the middle and rear drums. To unload the middle drum, however, the first row of tubes in the rear bank are connected to it. These tubes thus serve to conduct the excess water to the mud drum directly.

The second design, B, was the first step taken to reduce the turbulence caused by the front tube bank discharging into only one drum. In this design, the front tube bank is split, part entering the front drum and the remainder entering the middle drum. The usual steam and water circulators, from drum to drum are provided. The third design shown, C, is probably the most important change that has been made in bent-tube boilers. In this case, alternate sections of tubes in the front bank are connected to the front and middle drums, alternate sections of the second bank are connected likewise. This arrangement distributes the steam generated in the first and second banks of tubes equally to the two drums. The steam in the most active tubes is discharged close to the water line. Turbulence of the water in the drums is minimized, resulting in more even water level and drier steam at all outputs. Because of the free circulation, the water level of this boiler is not subject to excessive fluctuations, even with wide variation in load. Separate steam circulators connect the rear drum with the front and middle drums, thereby delivering steam from these drums directly to the outlet drum. Water circulators connect the middle and rear drums and equalize the water level when the load changes.

The circulation characteristics of the three-drum boiler are similar to those of the four-drum type. The best designs are those in which the first and second tube banks are connected to the front drum. In this case, the second tube bank will serve as downcomers to the mud drum, and thereby partially relieve the front drum of the water burden. Less moisture is therefore carried over by the steam into the rear drum. Tabulated data, however, indicate that the drum volume provided must equal that of the conventional four drum type.

Two stages in three-drum bent-tube boiler design are shown in Fig. 4. In the first illustration, D, the front tube bank is relatively shallow, and discharges below the water line into front drum. The second tube bank is relatively deep and makes up the second and third passes of the boiler. The tubes of this bank discharge into the rear drum. Several rows of water circulators are necessary to unload the front drum, as all of the tubes in the front bank are risers. Because of this condition, violent turbulence and uncertain water level conditions exist. The steam from the front drum, therefore, carries a high percentage of moisture. This wet steam is conveyed to the rear drum through several rows of gas-swept steam circulators. This is necessary so that the steam entering the rear drum will not carry excessive moisture, making drying almost impossible. The second illustration, E, shows a three-drum boiler provided

with a deep front bank. The tubes in this bank are split into two sections, and form the first and second passes of the boiler. The second bank of tubes, entering the rear drum, form the third pass of the boiler. In this design, we have a certain amount of recirculation in the tube bank, composing the first two boiler passes. The turbulence in the front drum is minimized. Two rows of steam circulators, that are not gas swept, carry the steam to the rear drum. Water circulators are provided to equalize water levels.

The two-drum type of boiler is well known for its wet steaming characteristics, when forced. This difficulty may be minimized by increasing drum diameter and length. If sufficient liberating volume cannot be obtained in this manner, it is then necessary to provide a dry drum of sufficient capacity. Experiments have been conducted in such boilers having extended drums. Baffles were provided and the steam taken from the relatively quiescent zones near the drum ends. Liberation rates, for obtaining dry steam, were greatly in excess of those permissible in the short drum type, provided with ordinary deflectors and dry pipes.

Two designs of the two-drum bent-tube boiler are shown in Fig. 5. In this case the main tube bank of each boiler is practically the same except for arrangement of tubes. The principal difference is that one boiler is provided with a "dry drum," from which the steam is taken to the header. In the other the steam is taken directly from the upper boiler drum through a "dry pipe."

In presenting the foregoing data and analysis, no reference has been made to the amount of heating surface in any of the installations. By the old conventional standards, ratings varied from 200 to 1200 per cent. But of what value are such arbitrary standards? Furthermore, practically all of the units were equipped with water-cooled furnaces. The extent of this cooling varied from one wall covered, to complete furnace coverage. This had no particular bearing on the discussion. Of course, if the risers from the water walls are improperly connected to the drums, conditions

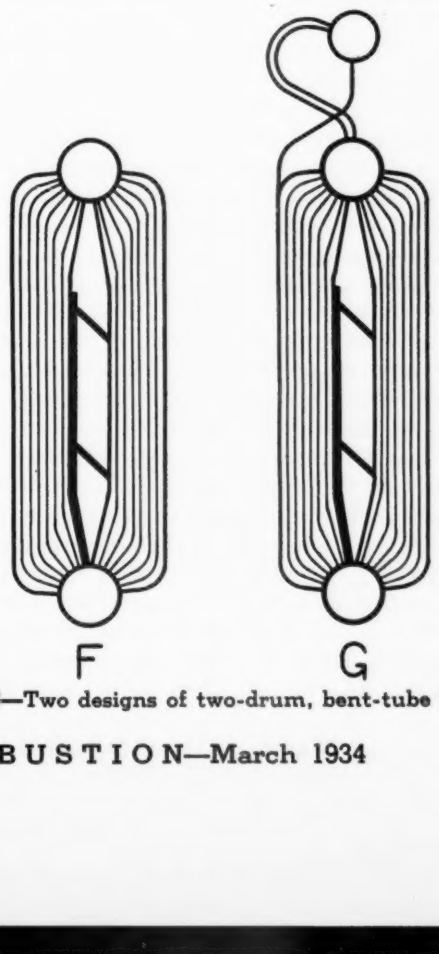

Fig. 5—Two designs of two-drum, bent-tube boiler

causing moisture carry-over may be set up. It must be presumed that, if equipment of this type is installed, the manufacturer has had sufficient experience to execute a proper design.

The data presented are based on installations now in actual operation. It must therefore be borne in mind that these data are indicative of past rather than future practice. The one exception is plant 23. The results, in this instance, forecast what may be expected in the future.

It has been shown that the maximum liberation rate in boiler drums, for obtaining dry steam at varying pressures, follows a definite law. That this liberation rate is entirely independent of the amount of heat absorbing surface connected to these drums. That the outworn and overworked standard, "per cent of boiler rating," has no meaning or value in determining the maximum output that may be obtained from any given unit. Then why continue its use? Why not write specifications somewhat in the following manner: "The steam-generating unit shall be of sufficient size to deliver a maximum output of blank thousand pounds of steam per hour, having a moisture content of not more than one-half of one per cent. That sufficient surface shall be provided so that the boiler exit gas temperature, at blank thousand pounds per hour, shall be less than blank degree Fahrenheit. That the maximum draft loss, at this same output, shall not exceed blank inches water gage, etc. etc." Having written a specification in this manner, the boiler manufacturer is now in a position to select the most suitable equipment to meet the conditions set up. The amount of heat-absorbing surface provided, will be sufficient to produce the specified exit gas temperatures. The furnace width and boiler passes will be so proportioned, as to maintain the draft loss at or below that specified as a maximum. The length and diameter of the steam drums will be great enough to provide the necessary volume for obtaining dry steam. This last factor is the one that determines capacity. The other factors determine the efficiency of the unit as a heat absorber. In all cases, for a given type of boiler operated at a stated output and pressure, the capacity factor, steam liberating space, remains constant.

The efficiency factor, on the other hand, may be changed. This is best illustrated by a definite example. In one plant a straight-tube boiler, forty rows high, was installed to give an output of 350,000 lb of steam per hour. The unit is of the single-pass type and operates on natural draft. The overall efficiency is 83 per cent. In another plant, an eight-tube high boiler, of the same furnace width as the one above, and provided with the same diameter and length of drums, also gives an output of 350,000 lb of steam per hour. However, in order to obtain the same efficiency, it is necessary to add a large amount of supplementary surface, in the form of an economizer and an air preheater. We have, therefore, varied the efficiency factor of the boiler, but its capacity factor remains the same.

The selection of the amount of surface to meet outlet temperature requirements, the proportioning of gas passage areas to give a resistance that comes within the maximum draft limits, and the furnishing of adequate drum volumes to insure dry steam at the maximum output, should be left to those whose installations cover a wide range of applications.

Factors Limiting Sensitivity and Accuracy of Test for Dissolved Oxygen

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While the maintenance of definite alkalinity values is important the author believes this to be secondary to the removal of oxygen. Investigations have shown that, because of temperature influence, the Winkler test for dissolved oxygen may not detect all the oxygen. It is therefore recommended that the water be cooled to 40 F after the reagents have been added and before adding the starch indicator.

DURING recent years many articles have appeared in the technical and semi-technical press concerning corrosion of steel, its causes and its prevention in boiler feed lines, economizers and boilers. This subject has become increasingly important as the negligible condenser leakage or contamination and the decreased percentage of makeup water in modern central stations result in a practically pure boiler feedwater supply. In many cases where this makeup is supplied by evaporators the total solids in the feed may be less than 3 ppm. The water with such a low solid content approaches the neutral condition (pH 7.0) and is easily adversely affected by otherwise inappreciable leakage or contamination.

In general the recommendations for the prevention of corrosion in boiler equipment and feed lines have been along the following lines:

1. Since iron dissolves in water when the pH value of the water is less than 9.6, the pH value of the water should be artificially raised to attain the value of 9.6 or higher.
2. Dissolved gases in feedwater should be removed by mechanical means (deaeration) as far as is consistent with economic operation.

Most operators have been careful to follow some such recommendations but there is at times some difference of emphasis or of relative importance given the two factors. The purpose of this article is to examine these requirements, discuss their importance, and if possible, point out the limitations in following them, particularly as regards the determination of completeness of removal of oxygen from the feed.

There seems to be a general agreement that the pH value should be in excess of 9.6 in the boiler. The values reported from central stations vary from 9.6 to 11.5. Dr. R. E. Hall states (COMBUSTION, Vol. 2, May 1931) that "so long as the pH value of the water is above 9.6 and the oxygen remains dissolved in the water no particularly deleterious corrosive action will occur. However, against a heating surface, the solubility of oxygen in water becomes less; hence bubbles may form and attach themselves at random to the surfaces." According to Dr. Hall's theory, these oxygen bubbles separate the metal from the alkaline water, thereby vitiating the effect of the alkaline water in inhibiting corrosion. This results in pits where the oxygen bubbles attach themselves to the metal surface.

With deaerating heaters working at 230 F, manufacturers will usually guarantee the delivery of water to contain not over 0.025 ml (or cc) of oxygen per liter. Modern deaerators, Dr. Hall states, "will give water sufficiently free of oxygen so that for all practical purposes any corrosion therefrom ascribable to oxygen is at a standstill." He refers to slight dissolution of iron in pure water and after the establishing of a minimum pH value of 9.6 emphasizes the importance of oxygen as the "quantity factor causing a sustained high rate of solvent action of water on the metal." His conclusions are that the water should have a pH value in excess of 9.6 and that with dissolved oxygen not in excess of 0.025 ml per liter corrosion will practically, if not actually, cease.

On the other hand, S. E. Tray ("Practical Essentials of Feedwater Treatment" presented at a meeting of the Great Lakes Section of the N.E.L.A. at Chicago, April 4, 1932) considers oxygen as a "secondary factor in corrosion," and states that "too much emphasis has been placed on the complete removal of oxygen without due regard for pH value of the boiler feed."

These are statements of engineers who unquestionably speak from considerable experience and with knowledge of actual plant results, yet each stresses the importance of different factors for prevention of corrosion. Many operators have conscientiously taken both the precaution of high pH values stressed by Dr. Hall and Mr. Tray and at the same time have reduced the oxygen content of the feed to a point where it is supposedly zero or at least negligible and have yet not been entirely free from corrosion troubles. Operators of other plants have been reluctant to report completely their corrosion difficulties, feeling that to a certain extent such troubles reflected on the plant organization. In some few cases this may be true, but in the majority of cases it seems that the results secured have been limited by conditions beyond the average operator's control or at least limited by

lack of knowledge that he could hardly be expected to have had.

In one plant the specific recommendation for boiler water conditioning was to hold stated alkalinity values (which in practice meant pH values of the boiler water between 10 and 11.5). It was expected, as a result of this treatment, that water with this alkalinity would insure protection against corrosive action provided no excessive amounts of oxygen were permitted to enter the feedwater. Now what is "no excessive amount of oxygen?" Is it 0.03 cc per liter of water, 0.10 cc or 0.5 cc of oxygen per liter of water? Dr. Hall (*Ibid*) would not tolerate values above 0.025 cc while S. E. Tray (*Ibid*) is not afraid of 0.5 cc of oxygen per liter. Furthermore, with what accuracy can we expect to make determination of dissolved oxygen and what is the minimum amount that can be determined and is frequently referred to as "zero oxygen content?"

Difficulties in Determining Oxygen Content

In this article, relating to determination of the dissolved oxygen content of water, observations will be presented in order that the plant operator may understand more fully the difficulties involved in accurately determining the oxygen content of water.

The practical plant operator will often ask the plant chemist, "with a definite alkalinity value (or, in some cases where control is by pH value, with a pH value of say 11.0) what maximum oxygen content is permissible without the danger of corrosion occurring?" The author is convinced that the oxygen content of the water should be zero or as near thereto as attainable. The alkalinity value (or pH value) of the water seems of lesser importance than the oxygen content, provided the water is not on the acid side (pH below 7.0).

The recommendation that the water should have a pH value of at least 9.6 is based on the determination (J. W. Shipley and I. R. McHaffie, *Ind. & Eng. Chem.* 17, 381, 1925) that iron will dissolve in pure water (starting with neutral distilled water) until the pH value reaches 9.6. However, in concluding therefore that raising the pH of the water to 9.6 by artificial means, that is by adding sodium hydroxide, corrosion will cease, one important thing should be considered. The antecedent of the higher pH value of the water was the dissolution of the iron to give the water the pH value of 9.6. The presence of ferrous hydroxide in solution gave the water its alkalinity. It was further the presence of dissolved iron which prevented further dissolution of iron. Thus, in the absence of oxygen, iron will dissolve until the solution becomes saturated with ferrous hydroxide. Or specifically, if a bright piece of iron rod is immersed in a saturated solution of ferrous hydroxide, no iron will dissolve if the oxygen is completely absent. However, if this same bright piece of iron is immersed in a solution free of oxygen and dissolved iron salts, but to which has been added some sodium hydroxide to raise the pH to 9.6, the iron will dissolve (i.e., corrode) until a certain amount of iron has entered the solution. It is true, however, that the higher the initial pH of the water, the smaller will be the amount of iron dissolving. On the other hand, if no effort is made to free a water of all oxygen, the result will be corrosion in spite of any reasonable alkalinity or pH values of the water between 9.5 and 11.5.

Should we not conclude, therefore, that the primary aim of boiler feedwater control should be the elimination of all oxygen in the water? This is not to imply, however, that the maintaining of definite alkalinity minimums (or pH values) is not of importance but it seems secondary to removal of oxygen.

Basis of the Winkler Method

To control properly the oxygen content of water, it is imperative that reliable means of detecting and measuring the oxygen content should be used. At present, the best known test for determination of the oxygen in water is the Winkler method. Briefly, this method is based on oxidation-reduction principles. The reagents used are manganous sulphate solution, alkaline potassium iodide solution and sulphuric acid. When the reaction is completed starch is added to color the solution blue and the free iodine is titrated with sodium thiosulphate solution. The reactions may be expressed as follows:

In an alkaline solution any oxygen in the water oxidizes the manganous ion to manganic ion:

$$Mn^{++} + O \longrightarrow Mn^{++++}\ O^{=}$$
$$2^{+} \qquad \longrightarrow 4^{+} \qquad 2^{-}$$

manganous ion + oxygen manganic ion combined oxygen

In an acid solution the manganic ion oxidizes the iodide ions to iodine, thus:

$$Mn^{++++} + 2I^{-} \longrightarrow Mn^{++} + I_2$$
$$4^{+} \qquad 2^{-} \qquad 2^{+}$$

manganic ion + iodide ion ⟶ manganous ion + iodine

The liberated iodine, if in sufficiently large amounts, will color the solution yellow. In very small amounts the change will be imperceptible and starch is needed to color the solution blue.

From the foregoing reactions, it is seen that the amount of iodine liberated is a measure of the dissolved oxygen content of the water.

In turn the liberated iodine is titrated with thiosulphate ion. This reaction is as follows:

$$2 \quad S_2O_3^{=} + I_2 \qquad S_4O_6^{=}\ 2I^{-}$$

thiosulphate ion ⟶ tetrathionoteion

$$4^{-} \qquad\qquad 2^{-} \qquad 2^{-}$$

But, if the Winkler method for the determination of oxygen reveals no oxygen, as evidenced by the failure of the starch to turn the solution blue, can the chemist be sure that his feedwater is in fact free of dissolved oxygen? On some samples of water which the author tested for oxygen, the results showed apparently zero oxygen. However, when vapors were flashed from this water and these vapors condensed and tested, the results indicated the presence of considerable oxygen. These results led to further study with a view of disclosing the limitations of the methods of analysis for dissolved oxygen and attempting to improve them.

It is known that if the concentration of calcium in a feedwater is wanted, the chemist does not precipitate the calcium as $CaCO_3$ but rather as calcium oxalate CaC_2O_4. The reason is that calcium carbonate is more soluble than calcium oxalate. Hence, to get as much of the calcium out of solution as possible, the calcium is precipitated as calcium oxalate. Likewise, in determining the amount of iron in solution, the iron is not precipitated as ferrous hydroxide but as ferric hydroxide. The

reason for this is the solubility of iron as ferrous hydroxide is many times that as ferric hydroxide. In other words, in all chemical analyses the substance sought should be obtained as quantitatively large as possible. To do this, conditions are chosen which are the most favorable to complete precipitation.

Now, just as in precipitation of a substance which is sought in an unknown solution, 100 per cent of such a substance cannot be thrown down, so in oxidation-reduction reactions, of which the Winkler method for the determination of dissolved oxygen is typical, all the oxygen is not detected. To be more explicit, only a part of the total dissolved oxygen present in the water will undergo a change of charge or oxidize the manganous ion to the manganic state. Also, not all of the manganic ion formed by the oxidation of the manganous ion by the dissolved oxygen, will react with the iodide ion to liberate all the possible iodine. In short, then, there will be some dissolved oxygen not reacting with the manganous ion and some iodide ion not converted to free iodine by all the manganic ion present.

Fig. 1—The McLean sampling bottle

The author does not have available sufficient data to push the study to conclusion or enable the determination of what might be called the "unreacting" oxygen content of the water. But, from a study of the ferric-ferrous and iodide-iodine system by Fales (H. A. Fales, "Inorganic Quantitative Analysis" page 294) it is possible to estimate the order of its magnitude. Fales shows that when 3 gms of KI in 175 cc of solution are being oxidized by 25 cc of 0.1 molar ferric chloride solution, there is left 1.25 parts out of every 1250 parts of the ferric ion unreduced. Thus, in all oxidation-reduction titrations, the amounts of the ions titrated will always be less than the total amounts present.

It it is assumed for the present that the amount of "unreacting" oxygen is the same as the amount of "unreacting" iron, both of which are compared against iodide, it can be shown that the residual oxygen not reacting is on the order of 0.07 cc per liter of water. It would seem, therefore, that of the total amount of dissolved oxygen in water not all is detected, and furthermore, that this undetected dissolved oxygen is greater than the majority of authorities agree should be allowed in boiler feedwater.

The presence of this "unreacted" and/or other oxygen can be physically demonstrated if, as stated previously, in addition to drawing the water samples in the usual manner, the sample is flashed and the vapors condensed This method will often yield samples clearly revealing the presence of oxygen when tested by the Winkler method although tests of the original water gave negative results. The condensate of the flashed vapor presumably contains most of the dissolved oxygen in the original sample but in greater concentrations.

Consider also that to a 250 cc sample of water taken for oxygen analysis, there are added a total of 6 cc of reagents which must contain some small amounts of dissolved oxygen. This dissolved oxygen does not affect the test sufficiently to color the starch solution blue. It is recognized, too, that the concentration of dissolved oxygen in the reagents will be less than in the same amount of water since the reagents are concentrated salt solutions and, therefore, do not have the capacity to take such oxygen into solution as the purer water has. However, if such solutions contained only half as much oxygen as might be contained in an equal amount of pure water at the same temperature, the total oxygen added with the reagents at 70 F might be shown to approximate 0.036 cc per liter when 6 cc of the reagents are added to a 500 cc sample and twice that much when using a 250 cc sampling bottle. This amount is not additive to the "unreactive" oxygen previously mentioned but is of the magnitude to confirm the value arrived at and further demonstrates that the test has some limitations. If the amount of oxygen in the reagents approaches the amount of the "unreactive" oxygen then these two factors tend to offset each other and may be neglected and attention given to further factors which also adversely affect the sensitivity of the test. It may be naturally concluded, therefore, that the Winkler method has its limitations and does not detect all the dissolved oxygen in the water. This discussion has proceeded far enough to allow agreement that with such limitations inherent in the test, in order to make the determination of oxygen as reliable as possible, extreme care should be exercised in making the test in order not to introduce further errors.

The McLean Sampling Bottle

In the hands of trained operators practically any sampling method and bottle can be used. In less skilled hands, however, special designs are helpful. The McLean bottle has been found very satisfactory for rapid and accurate work. It is designed as shown in Fig. 1.

The cold water to be sampled is admitted to the bottom and allowed to overflow through the top stem for several minutes. When enough water has been passed through to flush the bottle thoroughly, the water is cut off and the glass cocks closed. The stems are then drained of water by shaking the bottle. The manganous sulphate is now added until the stem is full. The stem holds about 2.5 cc. The manganous sulphate solution is admitted carefully by opening the top cock first and then gradually cracking the lower cock. After both cocks are closed, the bottle is rotated and revolved to help mix the reagents in the bottle. It is important that not all the reagents be drained from the stem into the bottle. A little should be left in the stem to seal the main body of water from the atmosphere. The other reagents are added in like manner, making sure that the previous reagent is carefully washed out of the stem before adding the next reagent. The reagents should not be allowed to mix in contact with the air.

Having started with the proper sampling, care should be taken not to contaminate the sample or the tests will be valueless and misleading. Improper testing, it might be thought, would tend to show oxygen in the sample when in reality it is not present. This is not necessarily so. A serious contamination of the sample may take place which will indicate zero oxygen content when some oxygen is really present in the water. Such

contamination may be the result of using rubber tubing in transferring the reagents to the sampling bottle. Unless the rubber tubing is free of all sulphur, the tests are unreliable. Even after a rubber tubing has been boiled in NaOH solution to remove the sulphur, there may be enough reducing sulphur left in the tubing that when it is used to convey the reagent to the water sample, enough sulphur may be dissolved by the reagent (especially the alkaline potassium iodide) to reduce any iodine formed by the test. This results, of course, in low or apparently zero oxygen.

On the other hand, it is desirable to be on guard to see that the reagents are not contaminated by oxidizing reagents. The potassium iodide should be tested for iodates.

Starch is not sensitive to iodine unless a salt of iodine is present. In other words, the presence of some potassium iodide is necessary if the iodine is to sensitize the starch indicator to a blue color. The potassium iodide serves two purposes in the Winkler test. It supplies the necessary iodide to react with the manganic acid formed by the dissolved oxygen; and it also supplies the necessary potassium iodide to sensitize the starch indicator. There is ample potassium iodide in the alkaline potassium iodide solution to react with any amount of manganic acid formed by the dissolved oxygen in the water up to the saturation value for oxygen in water. However, the potassium iodide is associated with a considerable amount of potassium hydroxide. When sufficient potassium iodide is added to sensitize the starch indicator, an unnecessary amount of potassium hydroxide is also added. Accordingly, it is suggested that the amount of alkaline potassium iodide to be added to the water be reduced to one cubic centimeter. Then, after the completion of the test and just before adding the starch indicator, add at least 2 grams more of potassium iodide to 200 cc of solution.

According to Lottermoser (*Zeit. Electroch.* 27, 496, 1923) the blue starch solution is due to a hydrated colloidal sol made up of the soluble portion of the starch, iodide ion and iodine. As already stated, there must be present iodide ion as well as iodine. The soluble portions of the starch hydrolize to various dextrins in acid solutions. Where dextrins are present, starch does not yield a blue color but rather a purple to red color. If too much acid is in solution the starch may not yield any color at all. The pH value of the solution should not be less than 3.

After all the reagents have been added, it is popularly supposed that exposure of the sample to the air will not result in increasing the oxygen content. If the acidity of the solution is great enough, the oxygen of the air will liberate iodine, thereby turning the solution blue.

The sensitization of the starch indicator by the iodine in an iodide solution is a delicate affair and requires careful precautions to realize a blue color. The chief cause for the lack of sensitivity of starch indicators toward iodine in a potassium iodide solution is probably the temperature of the solution. The curve, Fig. 2, shows the sensitivity of a particular starch solution towards iodine in solutions of varying temperature. This curve is an average of a number of determinations. The true curve for any particular starch solution may be either to the right or left of this one, depending on the kind of starch used and the acidity of the solution. It is clearly seen that this curve apparently becomes

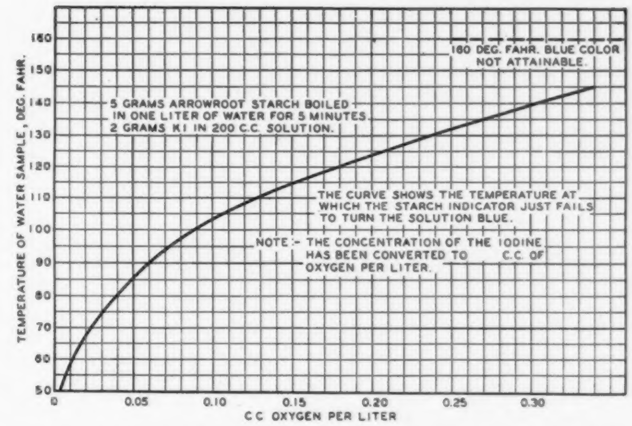


Fig. 2—Sensitivity of starch indicator for iodine in KI solution

asymptotic at about 160 F and beyond such temperature the starch is of no value at all. Its power to color the solution blue is destroyed. At 140 F, oxygen to the extent of 0.3 cc per liter will not be detected by starch, although the solution is yellow. At 120 F, the dissolved oxygen in the water may be 0.18 cc per liter before the starch turns the solution blue. At 90 F, 0.06 cc are undetected.

In the South where the raw water available for cooling samples is around 95 F in the summer, the sample may not be cooled below 105 F. At such a time the oxygen in the feedwater may be 0.11 cc per liter without being detected. Thus negative results by the Winkler test which it is often stated indicate, that the oxygen content is less than 0.025 cc per liter does not mean any such thing. The Winkler test is at its best a quantitative test only when the temperature of solutions is considered. This factor is not stressed in printed instructions for the Winkler test. One prominent deaerator manufacturer states that samples should be cooled below 150 F.

Influence of Temperature

In addition to this 0.11 cc per liter which the starch does not detect there is also, as previously discussed, an additional approximate 0.07 cc per liter which never entered in the chemical reactions of the Winkler test for oxygen. Thus, a possible 0.18 cc of oxygen per liter may be in the water without the analyst's knowledge when the temperature of the sample is 105 F. It is, however, within the analyst's power to reduce the error due to temperature. Starch, according to the curve previously derived, will be sensitive to very minute traces of iodine at temperatures approaching the freezing temperature of water. In order to make sure that the tests of the boiler feedwater for dissolved oxygen are not influenced by temperature the water might be cooled to 40 F in a refrigerator after the reagents are added and before adding the starch indicator. Then, when the starch indicator is added the solution will turn blue if only a very faint trace of iodine is present. When a feedwater passes the refrigerator test, if all other precautions have been observed, the operator can generally be satisfied with its condition as regards the elimination of dissolved oxygen. If trouble still persists, the further refinement of taking a flashed and condensed sample may be justified. Under ordinary circumstances this additional precaution is hardly warranted in the ordinary plant and, for all practical purposes, the water

may be said to contain "zero oxygen" and to be not harmful on the basis of the refrigerator test alone. For routine work and except as an occasional check, particularly in summer or the year round in southern stations, even the refrigerator test need not be resorted to. It does, however, give the operator means of occasional close checks on equipment performance and plant test methods.

For routine plant work for the Winkler test it is recommended that the sample of water be cooled to as low a temperature as possible; then, 2 cc of manganous sulphate solution added; mix and then add one cc of alkaline potassium iodide; mix thoroughly and then add just enough acid to barely dissolve the manganic acid formed. Add 2 grams of potassium iodide in the container for the 200 cc of solution and then add the starch indicator. Arrow root starch is recommended.

Further Investigation Suggested

The facilities at the author's disposal are naturally not complete enough to carry this study to its ultimate conclusions. Power plant chemists have lately come to general discussion of test methods in use and possibly this discussion will suggest further investigation elsewhere along these lines, with the ultimate object of refining the tests. For the present, if this article gives the ordinary plant operator a better understanding of the Winkler test and an appreciation of the limitations of such test and the factors involved in the accurate determination of oxygen, it will have served its purpose. In particular, the influence of the temperature of the sample has heretofore not been generally recognized or at least has been insufficiently emphasized as a factor in influencing the accuracy of oxygen determinations for feedwater.

It is entirely possible that, with refinement of testing methods, further progress will be made in accurately fixing the causes of corrosion and determining the factors which will inhibit such phenomenon. In the mean time, however, the plant operator should continue the use of the present tests guardedly and should review his past experience on this basis. If this is done, it is believed that operators and chemists will come to the conclusion that the elimination of oxygen is the major factor in the treatment of feedwater for the prevention of corrosion as long as the pH value of the water is above 7.0. The higher pH values have value but should not be unduly emphasized at the expense of elimination of oxygen from the feed.

Frank W. Kennedy, Vice-President and General Manager of the De Laval Steam Turbine Company, Trenton, N. J., died at his home at Yardley, Pennsylvania, on January 24, after a short illness. Mr. Kennedy was born at Pittsburgh, Pa., in 1876, and graduated from Princeton University with the degree of Civil Engineer in 1898. He thereafter occupied positions successively with the Pennsylvania Railroad at Altoona, the U. S. Steel Corporation, and the Dravo-Doyle Company, Pittsburgh. In 1908 he became General Manager of the De Laval Steam Turbine Company and in 1916 was elected Vice-President.

Classification of Coals by Rank

At the recent Annual Meeting of The American Institute of Mining and Metallurgical Engineers a paper was presented by Messrs. Selvig, Ode and Fieldner on "Classification of Coals of the United States According to Fixed Carbon and Btu." In this scheme the anthracite coals are divided into three groups, the bituminous coals into five groups, the sub-bituminous coals into three groups, and the lignite coals into two groups. The proposed classification follows:

CLASSIFICATION OF COALS BY RANK

Class	Group	Limits of Fixed Carbon or Btu Mineral-matter-free Basis
I. Anthracite	1. Meta-anthracite	Dry F.C., 98 per cent or more
	2. Normal anthracite	Dry F. C., 92 per cent or more and less than 98 per cent
	3. Semianthracite	Dry F. C., 86 per cent or more and less than 92 per cent
II. Bituminous	1. Low volatile	Dry F.C., 77 per cent or more and less than 86 per cent
	2. Medium volatile	Dry F.C., 69 per cent or more and less than 77 per cent
	3. High volatile A	Dry F.C., less than 69 per cent; and moist Btu, 14,000 or more
	4. High volatile B	Moist Btu, 13,000 or more and less than 14,000
	5. High volatile C	Moist Btu, 11,000 or more and less than 13,000
III. Subbituminous	1. Subbituminous A	Moist Btu, 11,000 or more and less than 13,000
	2. Subbituminous B	Moist Btu, 9500 or more and less than 11,000
	3. Subbituminous C	Moist Btu, 8300 or more and less than 9500
IV. Lignitic	1. Lignite	Moist Btu, less than 8300
	2. Brown coal	Moist Btu, less than 8300

The names given above under "Class" and "Group" are used temporarily, pending recommendations of the Technical Committee on Nomenclature, Sectional Committee on Coal Classification.

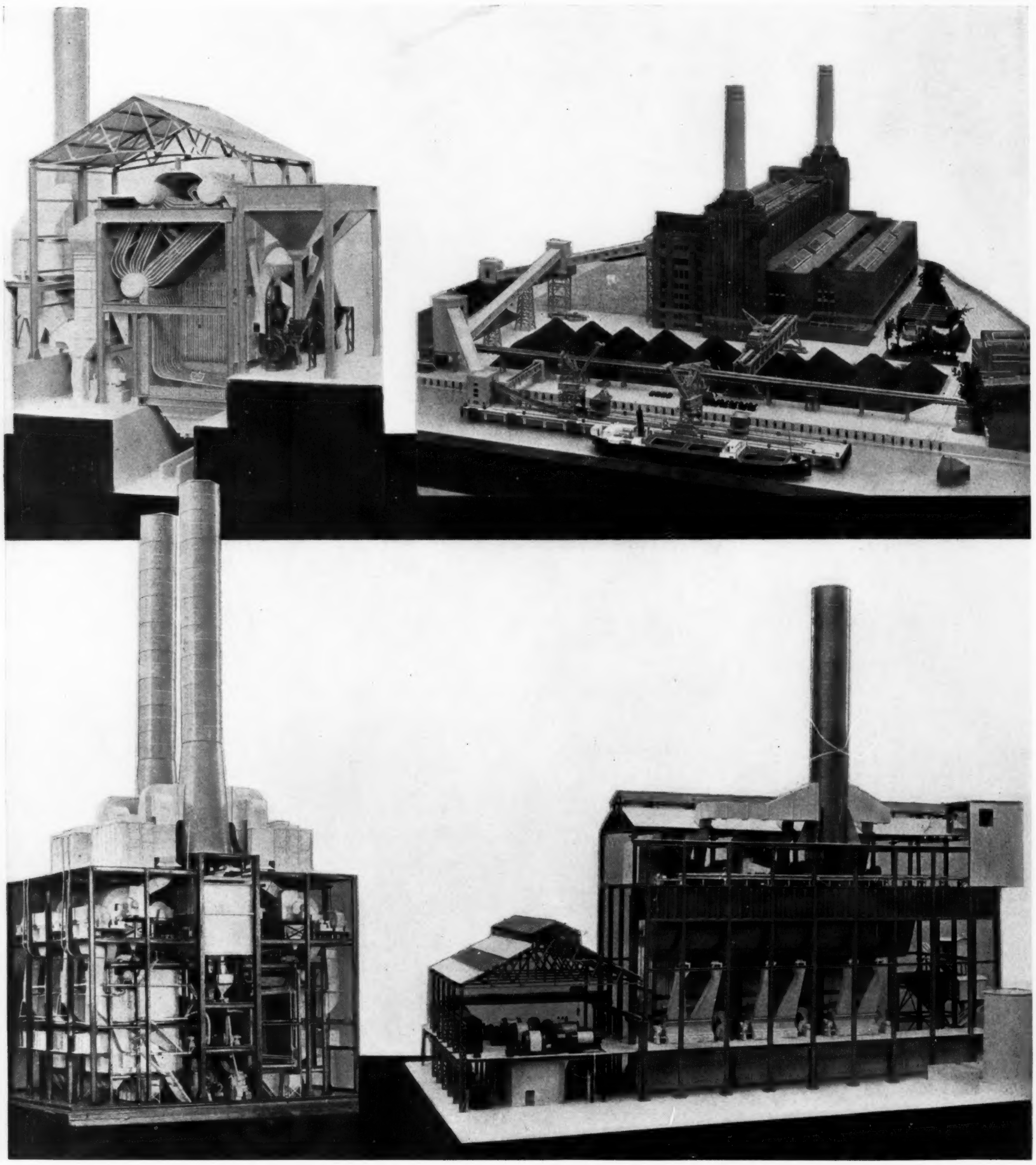
Fixed carbon on the dry basis free from mineral matter is used for marking boundaries between meta-anthracite, normal anthracite, semi-anthracite, low-volatile bituminous, medium-volatile bituminous and the first group of the high-volatile bituminous coals. Btu on the moist basis free from mineral matter is similarly used for distinguishing between the three groups of high-volatile bituminous coals and for the lower-rank coals. Coals having 69 per cent or more fixed carbon on the dry basis free from mineral matter are grouped according to fixed carbon regardless of their Btu values.

The Wilbin Instrument Corporation, 40 East 34th Street, New York City, has recently been formed to manufacture and market a complete line of electric instruments for the control of temperature, humidity, pressure, vacuum and liquid levels as used in heating, air conditioning, refrigeration and the process industries. The officers are Gus A. Binz, President, Clement Wells, Vice-President, E. A. Ileman, Director and Chief Engineer. Mr. Wells is President of Sarco Company, Inc., manufacturer of steam traps and heating specialties.

Gardner C. Derry who has been Sales Manager of the Power Division for the B. F. Sturtevant Company has been elected Vice-President of that company.

Frank E. Early, formerly of the Bailey Meter Company has become associated with the Trimount Instrument Company, Chicago, in the capacity of Chief Engineer of the Foto-Flo Meter department.

MODELS OF NOTABLE POWER



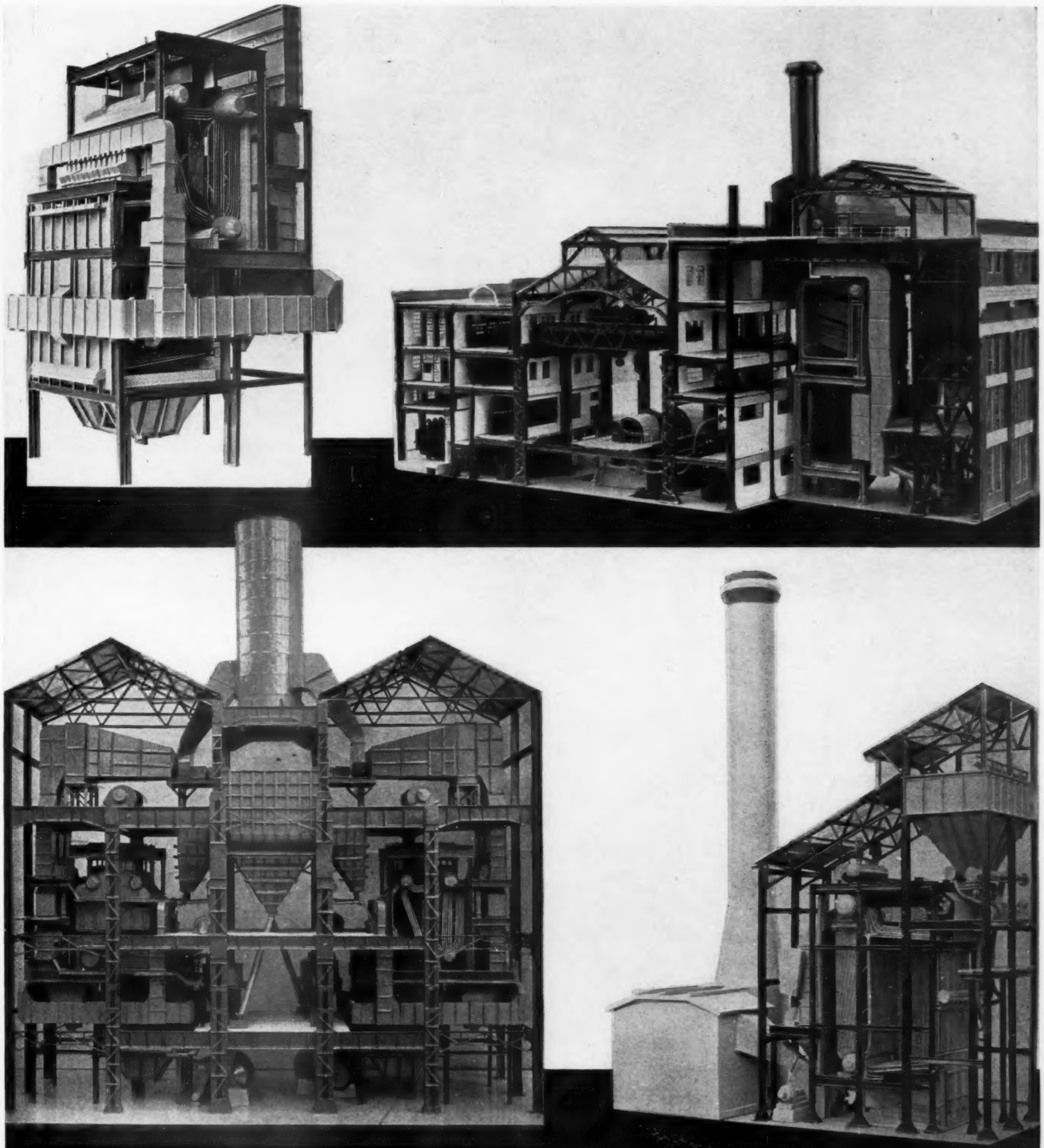
(*Upper Left*) Boiler plant of the Randfontein Copper Mines, Johannesburg, South Africa, containing two 4650 sq ft three-drum boilers, with water walls and fired with pulverized coal.

(*Lower Left*) Boiler plant of Brimsdown "B" Station, North Metropolitan Power System Co. Ltd. This contains two steam generators, each of 200,000 lb per hr maximum output, operating at 385 lb steam pressure and 780-800 F. It is fired with pulverized coal.

(*Upper right*) Battersea Power Station of the London Power Company. The present equipment includes six stoker-fired 330,000 lb per hr boilers operating at 650 lb pressure, 875 F, and two 67,500-kw turbine-generators. A 100,000-kw unit is on order. An elaborate system of washing the stack gases is installed.

(*Lower right*) Power plant of the Dartford Paper Mills. It contains 3 four-drum, stoker-fired boilers, each of 65,000 lb per hr capacity, operating at 475 lb pressure, 750 F, and three 3000-kw turbine-generators.

PLANTS OF BRITISH DESIGN



Photographs furnished through courtesy of International Combustion, Ltd., London

(*Upper left*) Part model of boiler unit at the Tir John North Power Station, which is now under construction at Swansea.

(*Lower Left*) Boiler plant of Tir John North Station, Swansea. This plant will contain four steam generating units each of 240,000 lb per hr steam output, operating at 650 lb and 850 F. The fuel burning equipment is of special interest in that pulverized anthracite duff will be burned.

(*Upper right*) Hams Hall Station of the Birmingham Corp. At present it contains five pulverized-coal-fired, 238,000 lb per hr boilers (maximum output) operating at 375 lb steam pressure and 710 F, and two 30,000-kw turbine-generators. An extension to the station will soon be made.

(*Lower right*) Congella Power Station, Durban, South Africa, containing six 60,000 lb per hr boilers and two 100,000 lb per hr steam generators operating on pulverized coal at 270 lb steam pressure, and 48,000 kw in five turbine-generators.

COMBUSTION ENGINEERING PRODUCTS

BOILERS

C-E Sectional Header Boiler
C-E Box Header Boilers
C-E Bent Tube Boilers
C-E H.R.T. Boilers
C-E Electric Boilers
C-E Marine Boilers

STOKERS

C-E Multiple Retort Stoker
Type E Underfeed Stoker
Type E Stoker-Unit *(for small boilers)*
Type H Stoker *(for industrial furnaces)*
Coxe Traveling Grate Stoker
Green Chain Grate Stoker *(natural draft)*
Green Chain Grate Stoker *(forced draft)*

PULVERIZED FUEL

Lopulco Storage System
Lopulco Direct-Fired System
Raymond Pulverizing Mills

WATER-COOLED FURNACES

C-E Water-Cooled Furnace
Lopulco Water Screen
C-E Slagging Furnace

COMPLETE UNITS

Coordinated designs comprising any combination of boiler and firing equipment and
Combustion Steam Generator
(a standard unit for medium-sized and large plants)
C-E Steam Generator Unit
(a standard unit for small plants)

OTHER EQUIPMENT

C-E Air Preheaters
(plate and tubular types)
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Grieve Grates
C-E Ash Conveyors
C-E Ash Hopper

Every well established type of fuel burning and boiler equipment exists for logical reasons. It meets certain fuel conditions or service requirements better than any other type. Combustion Engineering, with its complete line of equipment, is in a position to make recommendations based solely on the conditions and requirements of your particular plant.

REPLACEMENT of old boiler units

offers many manufacturing plants a possibility of effecting large savings

Take, for example, the case of a manufacturing establishment operating five 300 hp. boilers installed ten or more years ago. An average monthly efficiency of 65 per cent would be fair overall performance for such a plant.

By installing one thoroughly modern unit of sufficient size to carry the normal plant load, the average monthly efficiency could be increased to about 80 per cent, a cheaper fuel could be utilized, maintenance and other operating costs would be materially reduced, dependableness of operation improved, and numerous lesser advantages obtained. The overall savings would probably pay for the installation in from one to three years.

This general plan of modernization is sound from both engineering and economic standpoints and in many cases offers a real solution to the problem of increased production costs.

Combustion Engineering is exceptionally qualified to cooperate with plant engineers and their consultants in making studies which will indicate the economic possibilities of modernization either along these lines or by revamping existing boiler units.

Plant engineers are invited to make inquiry as to how a cooperative study of their problem may be arranged. There is no obligation.

COMBUSTION ENGINEERING COMPANY, INC.

200 MADISON AVENUE • NEW YORK, N. Y.

Canadian Associates, Combustion Engineering Corporation, Ltd., Montreal

A-114

Some Experiences with the Benson Boiler

Excerpts from a translation of a lecture by Dipl. Ing. H. G. Gleichmann on "Developments of Forced Circulation with Regard to the Benson Boiler in the Past and Future," given at the Siemens-Schuckertwerke, in which the author explains the cause of tube failures in the Benson boiler and the remedial measures that have proved successful. He also discusses regulation of this type of boiler as compared with those of the drum type. In the second part of his talk he proposes a system for plants with large variable loads. This will be abstracted in a subsequent issue.

EXPERIENCE has taught that every inventive thought which treads on new paths requires about a decade for fruition and must pass through many changes, and Benson's idea to employ the critical steam pressure for power plants has verified this statement. From the start it was clear that the simplicity of the basic thought, to have a boiler without a drum, running at critical pressure and providing useful steam for power production, would encounter difficulties in execution. Success of such a problem may not be attained alone by theoretical and purely laboratory investigations, but requires, simultaneously trials on a large and practical scale which yield the experience that leads to the design of safe operating installations.

The tube ruptures which always recurred after an uninterrupted run of some time in Benson boilers were assumed to be due to an improper arrangement of tubes, gas separation or to uneven distribution of water. Although these assumptions led to many improvements, the main difficulty, the deposit of salts on particular parts of the tubes, was discovered only after a longer experimental period, because no deposits of any kind were found at the places where the tubes had ruptured. The grate-fired experimental boiler in Bitterfeld disclosed the true situation after a series of failures. A treatment had been added to the turbine condensate, which served as feedwater, to correct the remaining hardness. When this was omitted the boiler could be run continuously without further tube ruptures.

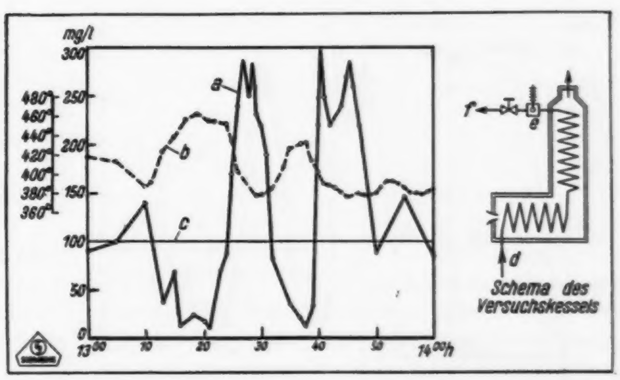
This discovery was followed up by exhaustive experiments on a small laboratory boiler in which the feedwater carried varying amounts of different salts. Fig. 1 represents a selected hour of a large number of experiments and shows the readings of salt concentration and temperatures at the boiler exit. The boiler was run so that the temperatures varied greatly at the point of measurement, and it may be seen that the salt content of the steam at that point varies inversely with the temperature changes. These experiments showed clearly that the salt deposit appeared on the tube wall only a short distance beyond transition of water into steam, i.e., at the beginning of superheating.

The remedying precaution against tube failures was found in placing this heating surface, which heretofore had been in a zone of very high gas temperatures and subject to radiant heat, into a zone of lower temperature.

The first practical result of this remedy was realized with the Benson boiler on the steamer "Uckermark" which had had several tube failures during its first voyage to Canada. After adapting this construction upon its return to Hamburg, the boiler has now run without mishap for nearly two years to the entire satisfaction of the owners.

At the same time the somewhat difficult reconstruction of the 40-ton boiler in the Kabelwerk of Siemens-Schuckert was undertaken, as well as the 100-ton boiler of the Centrales Electriques des Flanders et du Barbout in the central station at Langerbruegge, Belgium, all with equally satisfactory results.

The experiments provided an explanation as to why the tubes after rupture, were always found to be without coating and why ruptures occurred only after continuous operation. After shutting off the fuel, it was the practice to run the pump for a short time and the steam end of the tubes was washed with water which dissolved the salts. As all the installations were fed



a—salt content
b—temperature
c—salt content in the feedwater
d—feedwater entrance
e—point of measurement behind the superheater
f—steam outlet

Fig. 1—Salt experiments at critical pressure

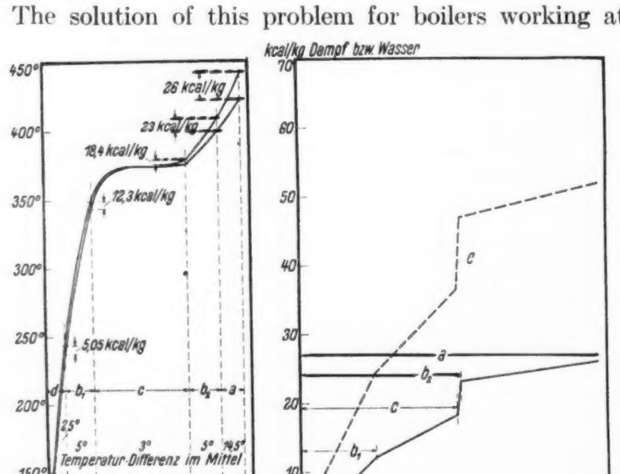
with turbine condensate and evaporated makeup, the non-soluble residues could deposit only in small quantities and only at those places where deposit of the soluble salts occurred; for at critical pressure, steam bubbles do not form on the water-heating surfaces, which would have permitted the burning on of scale.

The small amounts of non-soluble residues within the salt deposit are mechanically removed by the dissolving of the remaining salts. Since the deposit occurs in a relatively short tube length one can approximate the time in which, in accordance with the salt content of the water, the deposit should be removed.

The usual reduction of causticity in drum-type boilers must also be employed in the Benson boiler by a washing process, the time of washing being governed by the salt content of the feedwater. Every shutdown represents such a washing process, whereby the salt deposits, which may have lodged in very small quantities within the superheater, are removed. When continuous operation is required, washing is accomplished under load by subdividing the tube bundle so that some parallel coils may be separated and washed while the remaining coils are kept in circuit. This washing water is discharged into a tank and the water is passed through a heat exchanger and wasted, if it is not used for evaporators. With uniform firing the pump capacity must be increased by the amount of wash water. By washing such separate coils in rotation, all are eventually washed. Compared to the drum-type boiler, where blowdown is regulated by the caustic content, the washing process permits the use of less water at higher concentration for the salt removal.

The regulation of the Benson boiler differs basically from that of ordinary boilers only in that water, as well as air and fuel, must be continuously coordinated with the steam output. In boilers which have drums steam, at times, may be taken from the boiler at a higher rate than the feedwater is being supplied, with a resultant drop in water level. Also, more steam may, at times, be removed than is compensated for by the fuel and air, with a consequent pressure drop. The first condition is possible only within certain limits. Steam removal and boiler feed must on the average be the same.

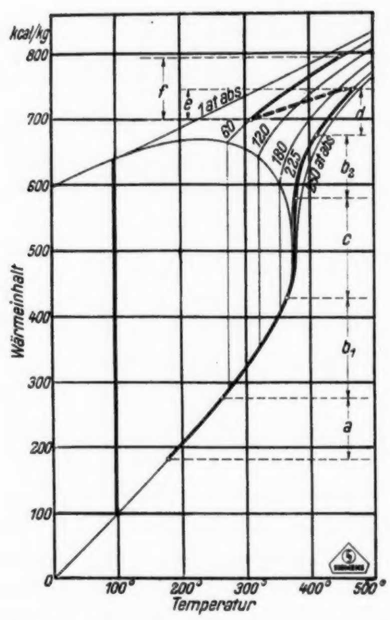
The solution of this problem for boilers working at



a—superheater
b_1—radiant heat part I
b_2—radiant heat part II
c—transitional part (water to steam)
d—radiant heat preheater

a—lag in regulation up to back of superheater
b_1—lag in regulation up to back of radiation part I
b_2—lag in regulation up to back of radiation part II
c—lag in regulation up to back of transitional part
d—lag in regulation up to back of radiant heat preheater
e—100 per cent over-regulation

Fig. 2—Regulation Langerbruegge



a—radiant heat preheater
b—radiant heat part I
b_2—radiant heat part II
c—transitional part
d—high-pressure superheater
e—turbine
f—interstage superheater

Fig. 3—Total heat-temperature diagram of boiler at Langerbruegge

the critical pressure is quite simple. A valve placed in the steam line is so regulated that a constant pressure is maintained within the boiler. In general this valve is automatic although this is not absolutely necessary. The valve therefore releases only as much steam from the boiler as there is feedwater pumped into it. A variation in delivered steam output may therefore be attained only by varying the boiler water fed.

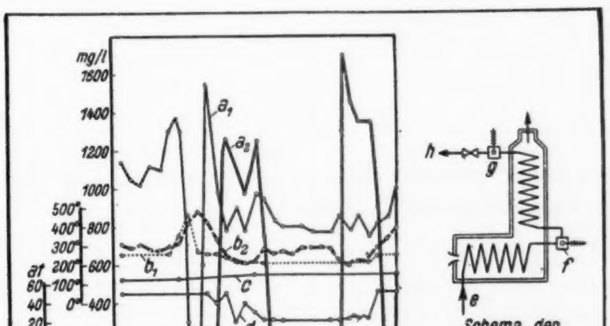
Steam pressure is therefore not a regulating medium. Depending on the installation, controls may vary. Where low-pressure units are involved, in addition to the Benson boiler, and where the Benson boiler serves as a superimposed unit, it is recommended that the low-pressure be chosen as a starting point for load regulation. Independent units have an electric load meter for controlling the output, which records the electric output of the station and has a second scale that shows the corresponding steam requirements. It is the duty of the attendant to correlate the actual steam output with that indicated on the electric meter as the steam requirement.

Operation at pressures below the critical, is slightly different. The valve located after the boiler, which maintains a constant critical pressure, may be omitted; in fact one may consider it to be full open. The pressure will then adjust itself in accordance with the load. The boiler pressure then varies with the load on the prime movers and the same pressure will automatically readjust itself with each load. Otherwise, regulation is precisely the same as in the critical boiler, although simplified by the omission of the pressure regulating valve at the boiler outlet.

The second characteristic of ordinary boilers, previously referred to, namely, that they are capable of furnishing for a time more steam than the instantaneous fuel supply will warrant, is likewise present in the forced-circulation boiler, with the difference that, at first, the steam temperature leaving the boiler will drop instead of the pressure. The accumulated heat storage

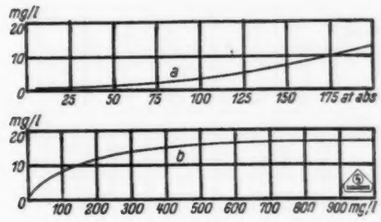
of a forced-circulation boiler depends upon the temperature drop of the metal walls of the heating surface, with the steam temperature, which releases heat for the generation of steam. Calculations for the Benson boiler at Langerbruegge show that for a steam temperature drop of 20 C, involving a heat release of 144,000 kg cal, half from the water-steam content and half from the heat stored in the heating surfaces, a 10 per cent peak above normal load may be met for about $1^1/_2$ minutes. This time is sufficient, when sudden load surges occur, to permit response of the regulating device. Where, in ordinary boilers, regulation is accomplished by steam pressure, the forced-circulation type requires the regulation to be influenced by steam temperatures at the outlet at both critical and below critical pressures.

As may be seen from Fig. 2, the forced-circulation boiler has quite a large lag before regulation sets in when controlled by the steam temperature at the boiler outlet. It becomes clear that a response to regulation may only fully register when a water particle has completely traveled through the boiler. About three minutes elapse for water to flow through the Benson boiler at Langerbruegge at full load, and at partial loads a longer time is required. Added to this lag is the requirement to bring the heating surfaces to another temperature level. If the steam temperature leaving the boiler is to be raised 20 C and firing is to be so changed as to produce the new condition, Fig. 2 (left) shows how the temperatures change within the several heating surfaces and gives also the heat requirement to bring the tubes to the higher temperature level, Fig. 2 (right) shows the corresponding lags for the various heating surfaces. Nearly nine minutes pass until the new condition sets in. This could be offset by over-regulation in order to shorten the time but, even so, the time element would be too long to guide the boiler along constant steam temperature by means of an instrument placed at the boiler outlet. Fig. 2 also shows the way out. Radiation part I (b_1) brings about the new condition in about $2^1/_2$ minutes. Since the outlet temperature of b_1 bears a given relation to boiler outlet temperature, regulation may be accomplished at this point, because variations may be practically anticipated there. This scheme was successfully used at Langerbruegge.



a_1—salt content back of the radiant heat part
a_2—salt content back of the superheater
b_1—temperature back of the radiant heat part
b_2—temperature after the superheater
c—salt content of the feedwater
d—pressures
e—feedwater entrance
f—measuring point back of the radiant heat part
g—measuring point back of the superheater
h—steam outlet

Fig. 4—Salt experiments on Kabelwerk boiler



a—variation of salt content in steam with pressure at 425 C superheat temperature and 25 mg per liter salt content in feedwater
b—variation of salt content in steam at constant pressure of 100 atmos (425 C) and different salt contents of feedwater

Fig. 5—Showing influence of salt content of feedwater on salt content of steam

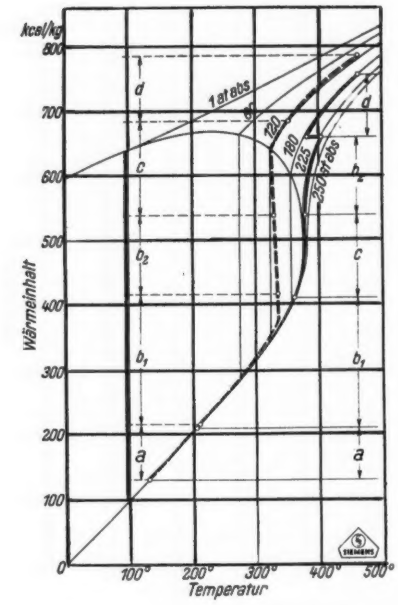
It must be clearly understood that the described lag in regulation has nothing to do with the flexibility of the boiler but deals with only the steam temperature regulation. Should it be desired to change the total load on the boiler, one must simultaneously vary fuel, air and boiler feedwater in proper proportions which may be accomplished by mechanical or electrical coupling of these three regulating means to a single control. No change in steam temperature enters into such control.

The basic requirements for safe operation of the forced circulation boiler are then:

(1) To have that portion of the heating surface, in which steam formation occurs and superheating begins, located in a zone of low temperature. (2) Regulate, not by pressure as in ordinary boilers, but by the final temperature of the steam leaving the boiler, wherein, because of the lag in temperature indication of such an instrument, a second instrument, located in an earlier part of the heating surface, is employed. (3) Feedwater must be thoroughly softened, as is the case for every high-pressure boiler.

Fig. 3 shows in a total heat-temperature diagram the range of the various heating surfaces of the Langerbruegge boiler. The part where vaporization takes place must have a certain play below and above the critical point in order that irregularities of operation because of different fuels, conditions of firing and feedwater temperature may be allowed for.

A series of experiments with pressures down to 30 atmospheres were conducted on the small experimental boiler at Kabelwerk, which showed that with proper location of the steaming zone and the first superheating zone beyond the hottest gas zone, that no tube ruptures occurred and that salt deposits occurred in a definite part of the heating surface, even more so than at the critical pressure. These experiments were repeated in the first Kabelwerk boiler, together with the determination of whether dry steam may be had with a large number of parallel groups of tubes. The results were equally satisfactory as with the experimental boiler. Fig. 4 shows similar curves as Fig. 1 for low pressures. In addition to the measurements taken at the boiler outlet provision was made for measurements between the radiation and correction parts. It was found that as pressures were lowered, the already low salt content in the steam became even lower, and, above critical pressure up to 300 atmospheres, that the salt content rose. Apparently then the density of the salt carrying medium has an influence on the salt deposit. The influence of the velocity and turbulence of the medium has not been finally determined in that the practical application does not permit higher velocities, due to



a—convection preheater
b_1—radiant heat part I
b_2—radiant heat part II
c—transitional part
d—superheater

Fig. 6—Total heat-temperature diagram of boiler at the Kabelwerk

excessive pressure drop. Fig. 5 shows the influence of salt content of the feedwater on the salt content of the steam. It must be assumed that the salt particles have a certain capacity for adherence during the transitional stage from the fluid to the crystalline state. Perhaps this may be attributed to the fact that the superheat temperature of pure steam still represents a state of moisture for concentrated caustic. Even if the physical reaction, when deposits occur, cannot as yet be viewed as clarified, the many control tests and the practical experiences leave no doubt as to the accuracy of the fact, that a complete salt deposit occurs within the boiler tubes at both the critical and pressures below the critical.

It was now decided to operate the boilers on the Uckermark and the Kabelwerk below the critical pressure. The heating surfaces of both boilers were reconnected so that the zone at which steaming ceases and the first stage of superheating begins is located in a cooler gas stream. Fig. 6 shows on a total heat-temperature entropy chart the rearrangement of parts of the second boiler at the Kabelwerk. Both boilers have now been operated for some time and the marine boiler runs at uniform load at 70 atmospheres measured after the superheater. The boiler at the Kabelwerk runs between 180 atmospheres and 40 atmospheres meeting the load demands of the works. Both run without difficulties and without salt deposits in the turbines.

The Elgin Softener Corporation, Elgin, Ill., announce the appointment of the L. A. Snider Engineering Service, 605 North Michigan Avenue, Chicago, as representatives of their entire line of water-conditioning equipment in the northern Illinois and Indiana territories. Offices will be maintained in Indianapolis and Peoria as well as in Chicago for sales and engineering service of the Elgin equipment.

Production of Electricity for Public Use

Figures on the production of electricity for public use and the consumption of fuels in the generation of electricity for such use during 1933 have just been released by the U. S. Geological Survey. The total production of electricity is given as 85,164,000,000 kwhr, an increase of about $2^1/_2$ per cent over that for 1932. This is somewhat more than the total production as given out by the Edison Electric Institute which was 79,017,666,000 kwhr generated and 2,894,258,000 kwhr purchased. The difference is due to deductions for certain plants not considered by the latter as public utilities. The percentage increase over 1932 is practically the same from both sources and weekly reports since the first of the year show a further steady increase. About 41 per cent of the total, according to Geological Survey figures, and 40 per cent, according to the Edison Electric Institute was generated by water power.

The increase in efficiency in the use of fuels for generating electricity is shown progressively since 1919. This is as follows:

Year	Output from Fuel, Kwhr	Net Tons, Coal and Coal Equivalent	Coal per Kwhr Pounds
1919	24,175,000,000	38,880,000	3.2
1920	27,248,000,000	41,240,000	3.0
1921	25,863,000,000	35,240,000	2.7
1922	30,234,000,000	38,000,000	2.5
1923	36,088,000,000	43,522,000	2.4
1924	38,808,000,000	43,130,000	2.2
1925	43,264,000,000	44,780,000	2.1
1926	47,274,000,000	45,856,000	1.95
1927	49,995,000,000	45,910,000	1.84
1928	52,793,000,000	46,387,000	1.76
1929	62,284,000,000	52,574,000	1.69
1930	62,514,000,000	50,654,000	1.62
1931	60,768,000,000	47,134,000	1.55
1932	48,931,000,000	36,600,000	1.50
1933	50,509,000,000	37,156,000	1.47

This saving in coal, through increased efficiency, is equivalent to about 750,000 tons, which at $3 per ton delivered would amount to $2,250,000.

During this fourteen period the generation of electricity by water power has increased from 37.5 per cent in 1919 to 41 per cent in 1933, but in three of the intervening years dropped to less than 34 per cent.

The total generating capacity, as given by the U. S. Geological Survey, is 36,232,545 kw whereas that as given by the Edison Electric Institute is 33,494,400 kw of which 71 per cent is in steam equipment. Comparing this with the 60 per cent of electricity generated by fuel, it is apparent that the hydro plants are run at a higher capacity factor.

Ingersoll-Rand Acquires General Electric Turbo-Blower Business

Ingersoll-Rand Company has acquired the turbo-blower business of General Electric Company and will consolidate it with its own turbo-blower department.

Ingersoll-Rand is a long-established manufacturer of blowers of medium and large capacities, for pressures ranging up to 100 lb, whereas General Electric has specialized in both single- and multi-stage units for a variety of services in low and medium pressures.

The manufacturing equipment previously employed by General Electric is being moved to Ingersoll-Rand's Phillipsburg, N. J. plant, where all types and sizes will be manufactured.

Removal of Sulphur Dioxide in Flue Gas*

Present-day demands for purity of air in large industrial communities have been responsible for stringent requirements in the operation of large central steam and power stations. The products of combustion include fly ash, tar compounds, sulphur dioxide, ammonia compounds and carbon particles. The present paper deals with only one of these products, namely, sulphur dioxide, its recovery and disposal.

By C. E. SCOTT

Research Assistant
Chemical Engineering Dept.
Columbia University

THE absorption of sulphur dioxide in flue gas presents a unique problem to the designing engineer. It is basically different from that of carbon dioxide removal in two important items: First, only part of the total issuing gas is treated, and second, very little can be expected in financial return on the investment. In the removal of sulphur dioxide all the issuing gas must be treated, and this is one of the chief designing difficulties of the problem. Varying conditions of gas flow and varying sulphur dioxide concentrations in the gas make it difficult to provide a design that is flexible enough to operate at maximum efficiency over the entire range. However, the writer will endeavor to show that from the known gas-washing operations as practiced by the chemical industries, and by the use of certain well-known laws, it would not be an impossible task to design washers to meet most or all of the requirements for the efficient elimination of sulphur dioxide.

It is now well known that there are resistive material films on either side of the absorption interface similar to those encountered in heat-transfer work. Experimental evidence as to the behavior of these films indicates that nearly the same type of laws govern the two cases. In order to show the similarity in these phenomena the point will be illustrated by a simple example.

If one were to take the case of heat transfer through a plate in an air preheater, it would be obvious that the heat flows in proportion to the temperature gradient on either side of the sheet. It is well established that there are high heat-resisting films adjacent to the plate walls on either side of the sheet. These films hinder the flow of heat to such an extent that they are said to be of controlling importance; that is, different metals of lower heat resistance could be substituted but still approximately the same amount of heat would flow. The equation for the simple flow of heat is,

$$W/\Theta = H \times A \times \Delta T$$

where W/Θ is the heat transferred per unit of time, H is the overall coefficient, A the area of heat flow and ΔT is the "driving force" or temperature gradient.

Now let us consider the case of absorption. For the sake of discussion assume a small quantity of liquid and consider that there is a small quantity of gas over this liquid, which does not react chemically with it. The gas will dissolve as long as there is a difference between the concentration of the gas above and that in the liquid, expressed in the same units.

In absorption work the partial pressure unit assumes an importance similar to that of the temperature driving force in heat transfer work. It is as common to speak of the mean partial pressure driving force in millimeters of mercury, as it is to speak of the mean temperature driving force in degrees Fahrenheit. It is also recognized that there are well established films on each side of the interface, similar to the resisting films on each side of the heater plate previously mentioned. It has been found that both classes of resistive films, heat and material, are affected alike. If the gas is swept across the surface of the heater plate at a faster rate, all other conditions remaining constant, the film thickness is decreased due to the rapid scouring action of the gas, and more heat is transferred per unit of time. This is also true in the case of the absorption film. If the gases are swept over the surface at a greater speed, all other conditions remaining constant, the gas film resistance is decreased, and more material is transferred from the gas to the liquid phases per time unit.

However, it has been found that certain gases have controlling gas and liquid film resistances. That is, a certain gas may have a high gas film resistance and comparatively low liquid film resistance. Here the gas film may be said to be of controlling importance, and influenced only by conditions which would tend to cut down that resistance. Any attempt to cut down the liquid film would be useless. A critical survey of gas film resistances or coefficients is beyond the scope of this paper, the interested person is referred to any standard textbook of chemical engineering.

Gas will dissolve in the liquid until the equilibrium point is reached. If the liquid contains a greater amount of gas than that corresponding to the amount in equilibrium, gas will pass from the solution to the air above until the solution is in equilibrium again. This fact is made use of in the chemical industries by stripping a liquid of its volatile component. The simple equation for the absorption of a gas in a liquid is as follows:

* Presented by the Power Division of the A.S.M.E. before the Metropolitan Section, New York, February 7, 1934.

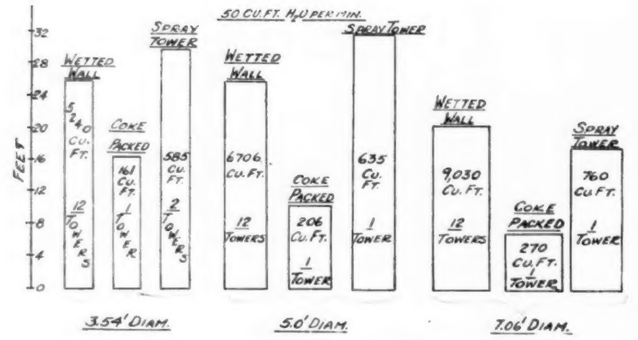


Fig. 1—Tower capacities to remove 94 per cent SO_2 from 1000 cu ft per min at initial concentration of 5 per cent SO_2

$$W/\Theta = K \times A \times \Delta P.$$

where W/Θ is the amount of material transferred per unit of time, K is the overall absorption coefficient, A is the total reacting surface, and ΔP the partial pressure driving force. The similarity in the equation for the transfer of heat and material is striking.

The foregoing may seem simple, but the broad principles underlying this theory are important if the following discussion is to be understood. It will be the writer's next step to show how the absorption constants (which are not constants at all, but are so named by the position which they take in the above equation) are of controlling interest and the designer's chief worry in the efficient design of an absorption tower.

The usual procedure of design has been rather hit and miss, but through many experimental towers of various shapes and sizes the overall coefficients have been pretty well established. This overall coefficient is then used with caution in the design of the larger tower. Needless to say, some of the towers built by this method are remarkably efficient. Usually a more exacting analysis is used, and even then the results are far from satisfactory. The removal of sulphur dioxide in a gas stream is usually accomplished by washing the gas with either water or a dilute alkali solution. The type of tower and the type of packing depend very much on the designer.

In order to give a typical problem encountered in the absorption industry the following example will serve to demonstrate how tower sizes are obtained.

Problem

Sulphur dioxide is to be removed from a flue gas which contains 5 per cent SO_2 by volume; 1000 cu ft of gas enter the tower per minute; the tower exit gas is not to contain more than 0.3 per cent SO_2 (an absorption of 94 per cent). Water flows down the tower at 50 cu ft per min. Gas enters at 150 F and leaves at 68 F. Entering water is at 64 F. Calculate the tower sizes for a wetted-wall tower, a spray tower and a coke-packed tower.

The basic equation used for this design is $W/\Theta = K \times V \times \Delta P$, where the same units have been used as before mentioned, but the interfacial area is unknown and the total volume has been substituted for it, since the K term also carries the area per cubic foot of tower volume. On solving the problem it is seen that 6.7 lb of SO_2 are to be transferred per minute. This is the W/Θ term of the above equation. The partial pressure of SO_2 in the entering gas is 38 mm Hg, the exit gas contains 2.28 mm Hg, and the exit liquor contains 9.4 mm Hg. The logarithmic mean between top and bottom, between gas and liquid, is found to be 10.4 mm Hg.

On consulting a standard text on chemical engineering the overall coefficient for these conditions of gas and liquid flow for a wetted-wall column is found to be 9.62×10^{-5}, for a packed column of coke 3.12×10^{-3}, and for a simple falling spray 1.02×10^{-3}. In other words the spray tower is eleven times more efficient than the wetted-wall tower for the absorption of sulphur dioxide, and the packed column is only three times more efficient than the spray chamber. It must be remembered that these figures are for the absorption of sulphur dioxide. Another gas, for example ammonia, may have the reverse order of tower efficiencies. Substituting the various

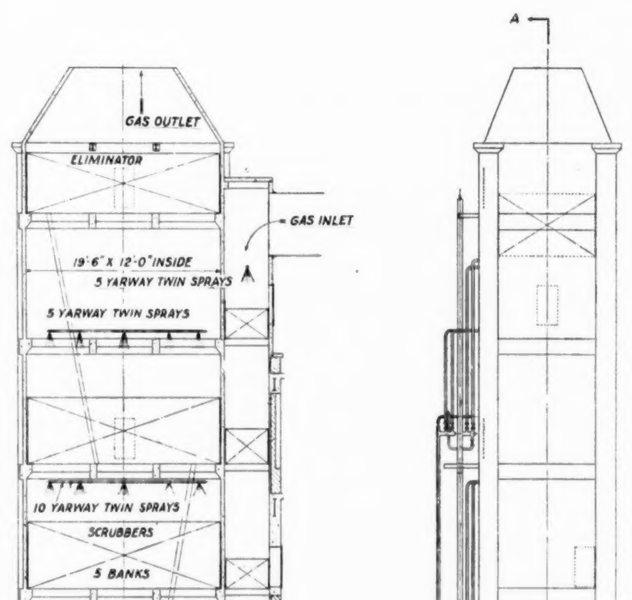


Fig. 2—Sections through gas-washing tower at Battersea Station

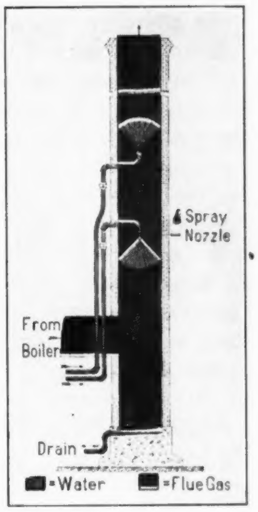


Fig. 3—Primitive type of gas washer

values of K in the above equation and solving for the volume, various tower volumes are found.

Fig. 1 indicates the variation of the coefficient by changing the tower diameter and thus affecting the speed of contact between the gas and liquid. It is noticed that the smallest tower volumes are obtained at high gas velocities, corresponding to small tower diameters. This advantage in volume saving is often counter balanced in operating costs for power to elevate the water to the top of the tower. The designing engineer would make a series of calculations and then determine the most economical design to fit the problem. Even then in the final analysis a large safety factor is employed to take up the "ignorance factor" in the design.

In the case of the absorption of carbon dioxide from flue gas the tower is operated at certain specified gas flows, and a certain quantity of carbon dioxide is removed per hour of operation. This is a simple straightforward design problem.

In considering the removal of sulphur dioxide, all the issuing gas must be so treated that the exit concentration of SO_2 must remain below a certain specified concentration. If the problem is to be commercialized, an efficient recovery must be made, and these two opposing factors must be reconciled to some mean value.

Perhaps one of the largest experimental absorption towers ever built for the removal of sulphur dioxide from flue gas is that at the Battersea Power Station in London. Several small towers were built, and from the data collected one large unit was constructed. It was made of cement and packed with wooden grids, the tower was 123 ft tall and $19^1/_2 \times 12$ ft inside. The scrubber surface was given as 34,000 sq ft. Experiments conducted with this large tower gave some very interesting results. Using cold water the best sulphur elimination was found to be 76 per cent. However, experiments were conducted with the use of dilute alkalis, and the following results were obtained; an 0.25 per cent soda ash solution gave an elimination of 95 per cent; an 0.25 per cent calcium carbonate solution gave an elimination of 92 per cent, and then an 0.2 per cent lime solution gave an exceptionally good elimination of 97 per cent.

The results also indicate that as the sulphur content of the coal is increased the efficiency of the tower is decreased, and to maintain a high efficiency more water and more alkali must be used. The cost of power and materials when operating with lime is reported to be equivalent to only 6 cents per ton of coal burned. The small amount of sulphur dioxide that is not removed in

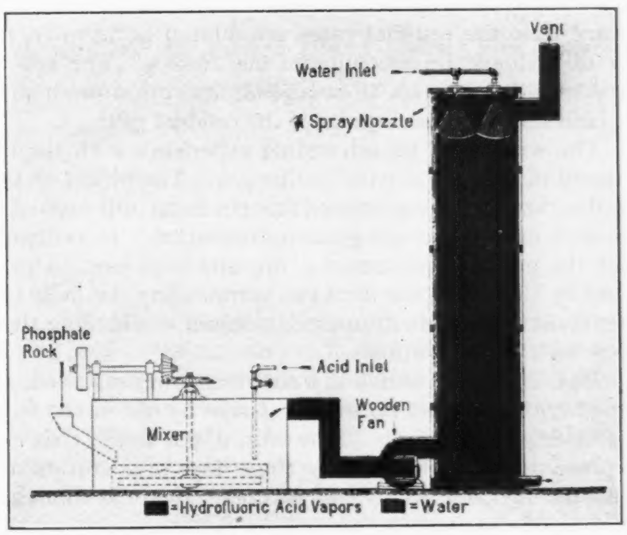


Fig. 5—Chemical spray tower

the flue gas is easily disposed of; by exhausting with the residual gases to the stack.

It has been found that an atmosphere containing about six parts of sulphur dioxide per million parts of air is

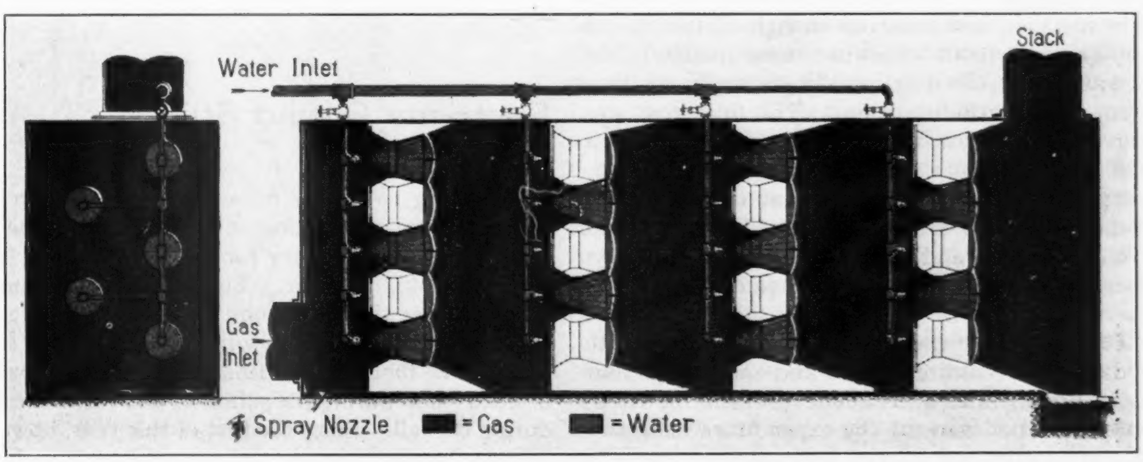


Fig. 4—Developed type of washer

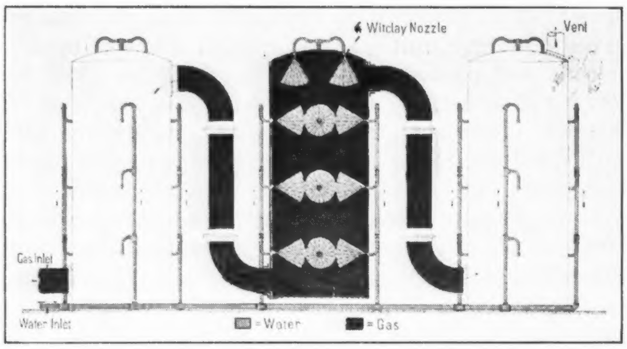


Fig. 6—A development in spray washing

obnoxious. If a power station were evolving gases to the extent that a concentration of ten parts per million of SO_2 was found in the neighborhood air, and then a gas washer of 70 per cent efficiency was installed, the surrounding air would not be obnoxious as a concentration of about three parts per million would result.

If a high absorption efficiency is obtained and at the same time the residual gases are diluted sufficiently, no trouble should be encountered due to SO_2. The key to the situation appears to be a good absorption tower plus a high stack for the disposal of the residual gas.

The writer had an interesting experience with the removal of sulphur dioxide in flue gas. The object of the utilization was to use washed flue gas as an anti-explosion hazard in a dangerous grinding operation. In ordinary air the grinding presented a fire and explosion hazard, and by the use of the inert gas surrounding the mills the reduction in the fire insurance premium would more than pay for the installation.

Pipe lines were laid, and a scrubber tower installed, all employing the most up-to-date design by one of the foremost engineering firms. However, it was found that the apparatus on the first two or three days of operation did just about half of what was expected. It would eliminate entrained dirt, but the removal of SO_2 was questionable. Consultants were called in, tests were made and it was found that the tower was operating at 98 per cent efficiency in SO_2 removal. The remaining residual SO_2 was in sufficient quantity to cause the closing down of the grinding rooms, as no employee could stand the choking gas. Here a few per cent of SO_2 caused enough trouble to shut down the entire equipment which was really working at peak efficiency. To remedy this trouble a second tower was installed and removed enough of the SO_2 to make the grinding room somewhat more livable. The problem was finally solved by installing a costly ventilating system in the grinding room. The final cost was about three times that of the estimated cost of the first apparatus.

This experience is cited to show that even traces of sulphur dioxide unlike those of carbon dioxide are extremely objectionable, and removal may be quite costly.

Another problem confronting the engineer is what to do with sulphur dioxide effluent from the absorption tower. To determine if the market can be supplied with sulphur dioxide, or oxidized forms and salts of sulphur dioxide, is a complicated economic problem in itself. If recovery does not warrant the expenditure necessary for all the apparatus and salaries for expert engineers to operate the equipment, then some disposal must be made at the lowest cost. However, if the recovery program appears to be economical the design for this part of the process would be similar to that for the recovery of carbon dioxide. Sulphur dioxide is evolved by a waste-heat boiler from the effluent, the gases are collected, washed and purified, and then compressed in an apparatus similar to that employed for carbon dioxide. Instead of a solid which is obtained in the case of carbon dioxide a liquid is produced when the compressed gases are expanded and cooled. This liquid boils at -8 C, or -25 F. It has a powerful germicidal action, and is known to be a strong bleaching agent. Sulphuric acid can be made from this material, but it would be much more economical to sell the sulphur dioxide and let some one else make the acid and other derivatives than to make the compounds at the boiler plant.

Compliance with State Laws

The disposal plant which would be incorporated in most designs would have to accomplish two things: first, it would have to neutralize any excess acid; and second, oxidize the effluent. Most states now have laws prohibiting the dumping of waste sulphite liquors in streams. Most streams will handle the acid satisfactorily but they cannot furnish the oxygen necessary to oxidize the sulphite to sulphate. If the liquor is dumped, as has been done in the past, the stream becomes devoid of fish, no sewage oxidizes, and it is transformed into an open sewer.

Oxidation is accomplished by neutralizing the solution with lime and then blowing with air, or blowing with air in the acid solution in the presence of a manganese salt. It would be advisable for designing engineers to keep in close touch with the state boards of health on this disposal matter. It is a good policy to have the latter approve of disposal methods before construction is undertaken. It is much more pleasant to have the cooperation of such departments than to have them as enemies. Most of the state departments of health have active laboratory staffs and equipment to handle most any stream-pollution problem. By a close cooperative policy an effective method of disposal could be worked out.

This brief treatment of the entire problem of absorption and disposal of effluent is indicative of the troubles that the designing engineer would encounter and by what means he might endeavor to surmount these obstacles.

Electricity Output Still Gaining

According to figures released by the Edison Electric Institute, the production of electricity by the electric light and power industry for the week ending March 3, was 1,658,040,000 kwhr. This represents a gain of 16.5 per cent over the corresponding week of last year and a substantial gain over that for 1932. Following a marked drop in the first four months of 1933, the output took a decided jump during the summer, and receded somewhat during the fall. Since the first of this year, however, the increase has been steady and the week of March 3 shows the highest output thus far this year.

The Regenerative Air Preheater

By C. EMIL CREUTZ

Engineer, The Air Preheater Corporation

In the November 1933 issue of COMBUSTION there appeared a comprehensive article by W. S. Patterson on the development and present status of the plate-type air preheater. The present article on the regenerative type was prepared to supplement the earlier discussion. In the case of the regenerative type, as applied to power plant work, the treatment is necessarily limited to a single design.

THE value of preheated air was recognized as early as 1815, when Robert Sterling of Edinburgh, proposed its use in connection with open-hearth furnaces. As fuel costs were then low the air preheater was not developed for greater economy, but to increase the temperature within the furnace, speed up the operation, and insure a uniform product of higher quality. The next important step in the development of air preheaters was that of the Simon Brothers, who designed a unit of the checker-work type and applied it to smelting furnaces. The design was crude but in principle very similar to the familiar refractory regenerator in use with the open-hearth today.

The introduction of the tubular, and later the plate-type air heater, occurred when the value of preheated air in boiler furnaces, both from the standpoint of increased economy and as an aid to combustion, was recognized. A most notable advance in air heater design was that invented by Dr. Frederick Ljungstrom, who conceived the idea of a preheater embodying a continuously rotating bank of steel heating surfaces to replace the heavy, cumbersome brick checker-work. This made possible the application of the efficient regenerative principle to boilers, as well as to industrial furnaces. This design also eliminated the fluctuating air temperatures, characteristic of the checker-work recuperator.

Other designs of regenerative air preheaters have been made, notably one in which the heating surface closely resembles that of the ordinary plate-type air heater, but, which by a system of large poppet-type valves alternately passes gas and air through a number of chambers arranged in parallel. While comparatively efficient as a means for recovering heat from combustion gases, difficulties in maintaining quiet valves, in preventing serious leakage and in finding sufficient space to apply this design, have limited its use to a comparatively small number of installations, few of which are in power stations. By a continuous study of current problems and by constant improvements in design, the application of the rotating air preheater has been widened to such an extent, that during the past ten years more than one thousand have been placed in operation.

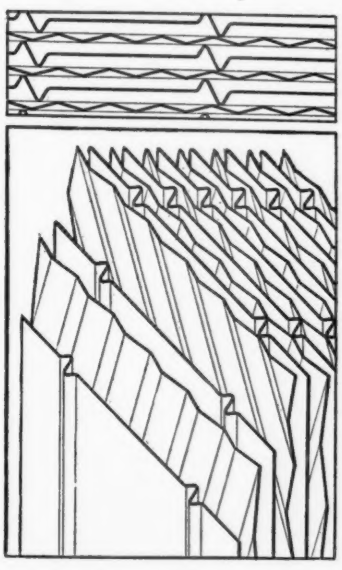


Fig. 1—The new Ljungstrom heating surface. Sheets with inclined undulations set between vertically notched sheets

In the present design the rotor containing the heating surface turns at 3 rpm, so that each portion of the heating surface is in the gas passage approximately ten seconds during each revolution. Any small amount of soot and fly ash collecting on the heating surface during this short period, is swept off during the next ten seconds by the air as it passes through the rotor. This characteristic permits the heating surface to be spaced much closer than is possible with the recuperative plate type, where good practice limits the width of the gas passages to a minimum of $^3/_4$ to 1 in. The rotor, therefore, is of relatively small diameter, and the rate of heat transfer is high, because of the high rates of gas and air flow and the narrow spaces between the heating surfaces. The ultimate result is that, with heating plates of only 23 to 28 in. in height, heat recoveries are equal to those of recuperative designs with plates 25 to 28 ft in length or with tubes 40 ft long.

Since the heating surface rotates, two stationary soot blowers of simple design are employed; one located above and the other below the heating surface. The soot blowers are effective because the heating surfaces are short, and all portions are well within the range of high steam jet velocity. Under similar conditions of

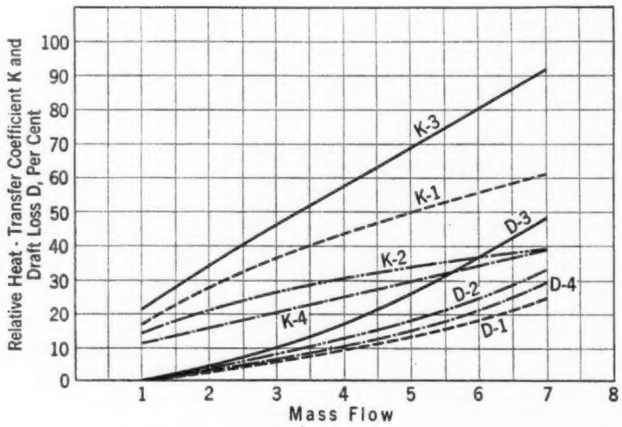


Fig. 2—Comparison of heat transfer and draft loss of three different shapes of Ljungstrom heating surface with 2-in tubes

operation, the rotating air heater has been less prone to clogging than other types.

Draft loss in an air heater varies in direct proportion to the length of the passages. For draft losses equal to those of other types much higher rates of gas and air flow can be employed and the area of the passages in the rotor reduced.

It is a well-known fact that gas temperatures across the width of every boiler uptake vary considerably. These variations, furthermore, continue throughout the length of the ordinary preheater. The reduced area of the gas passages in the rotor of the regenerative air heater and of the flues leading thereto, causes intimate mixing of the entering gases. The lowest plate temperature, therefore, is that which results from a true average of all of the gas. If at extremely low loads such mixing is not entirely complete, the coldest plate may be somewhat below the dew-point. But due to the rotation of the heating surfaces, this plate immediately passes to a region of warmer gases, and any moisture formed is evaporated. No portion of the heating surface is ever in a dead gas pocket, therefore, it is practical to reduce the gas temperature by means of the regenerative air heater to a lower exit temperature without danger to the heating surface, and thereby obtain a higher overall boiler unit efficiency.

The regenerative heater does not depend upon the ability of the heating surface to transmit heat from one side to the other, therefore soot deposits, if any, do not reduce the amount of heat recovered. The only effect common to the two types of heaters, as a result of building up of soot, is in the increased resistance to flow, which condition as outlined is easily remedied in the rotating type.

Various types of heating surface have been employed during the development of this air heater; all with the purpose of obtaining the most intimate contact of the gas and air with the heating surface, or in other words, to obtain the highest rate of heat transfer with the minimum resistance losses. The earliest form, consisting of alternated flat and corrugated sheets to form a multitude of small channels of triangular section was abandoned in favor of undulated and corrugated sheets. The most effective arrangement found to date is that shown in Fig. 1.

In this latest design, which has now been adopted as the standard, the crimped sheets have their undulations sloping at 30 deg to the path of fluid travel and in opposite directions in alternate sheets, and the corrugated sheets have been replaced by flat sheets, having longitudinal spacing ribs. These sheets form wide longitudinal passages, and their ribs are proportioned to keep the crimped plates far enough apart to give the most desirable sectional area to the passages. Fig. 2 shows the heat transfer and resistance to flow at the same velocities of three types of heating surfaces as compared with 2-in. tubes. Curves K-1 and D-1 indicate the performance of the notched undulated type now employed, and Curves K-4 and D-4 show that of 2-in. tubes. Curves K-2 and D-2, and K-3 and D-3, respectively, are for two earlier types of regenerative heating surfaces. It is to be noted, that for equal draft losses, much higher heat transfer is obtained with the newest type, which reduces the heating surface required, and therefore the size of the preheater.

Plate Material for High Temperatures

In the construction of the heater the plates after being formed, are grouped into segments which are placed in the revolving spider or rotor. If the heater has been designed for abnormally high temperatures, the plates and rotor are built entirely of heat-resisting metal, such as high chrome-nickel steel. Several have been operating regularly for a considerable time at gas temperatures over 1800 F. For more moderate temperatures, heating surfaces usually are divided into two parts, the cooler portion being made of ordinary open-hearth steel. For a maximum of 1000 F, the entire unit is constructed of this material. When the heater is to be used with boiler ratings so low that the average exit gas temperature is below the dew-point, the heating

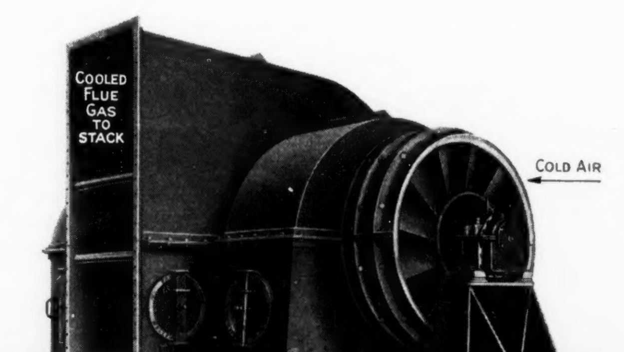
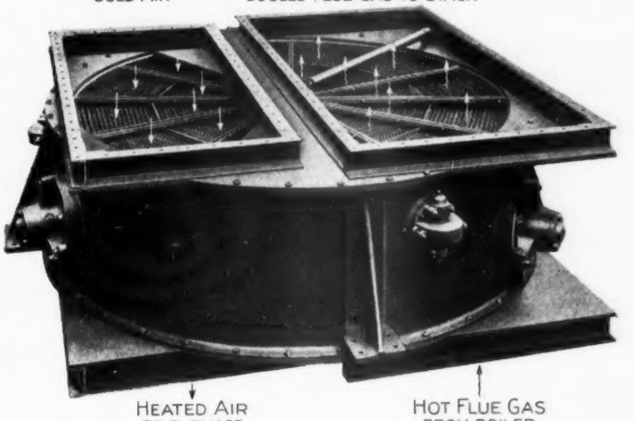


Fig. 3—Regenerative air preheater with integral air fans mounted on a single shaft

COLD AIR   COOLED FLUE GAS TO STACK



HEATED AIR TO FURNACE   HOT FLUE GAS FROM BOILER

Fig. 4—Small vertical-flow Ljungstrom regenerative air preheater for independent fans

surface is split so that it is only necessary to replace the portion subject to corrosion. The cost of the heating surface of a regenerative air heater is roughly 15 per cent of the total, thus reducing the cost of replacement to a minimum. This figure is further reduced by dividing the heating surface into two parts, as above stated.

The rotor casing revolves within the outer casing and an air space is provided between the two. Therefore, regardless of the gas temperature, the housing may be safely constructed of open-hearth steel, due to the insulating effect of the air.

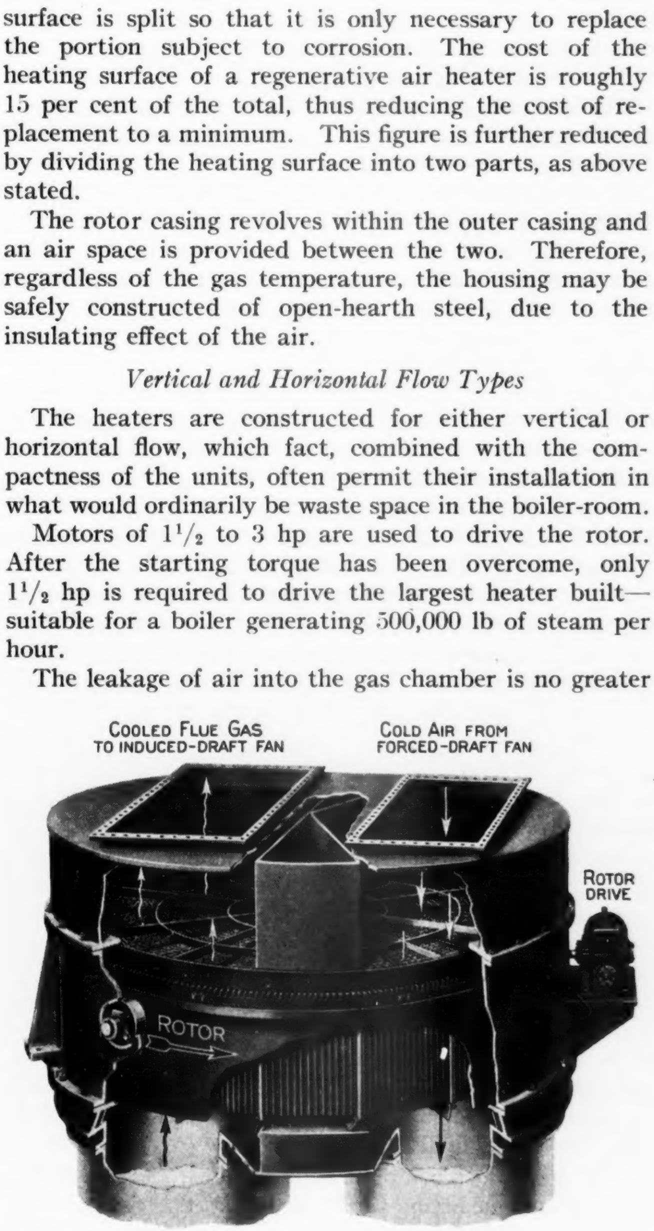
Vertical and Horizontal Flow Types

The heaters are constructed for either vertical or horizontal flow, which fact, combined with the compactness of the units, often permit their installation in what would ordinarily be waste space in the boiler-room.

Motors of $1^1/_2$ to 3 hp are used to drive the rotor. After the starting torque has been overcome, only $1^1/_2$ hp is required to drive the largest heater built—suitable for a boiler generating 500,000 lb of steam per hour.

The leakage of air into the gas chamber is no greater

COOLED FLUE GAS TO INDUCED-DRAFT FAN   COLD AIR FROM FORCED-DRAFT FAN



HOT FLUE GAS FROM BOILER   HEATED AIR TO FURNACE

Fig. 5—Large vertical-flow regenerative air preheater for independent fans

than in other types of heaters. Air leakage is minimized by flexible seals mounted on the top and bottom of the rotor. These are self-adjusting and remain so, even as the slight deformation of the rotor occurs. With reasonable care the amount of leakage remains constant during the life of the air heater, and is controllable at all times.

Earlier models were built almost exclusively with cylindrically housed integral forced-draft and induced-draft fans mounted on the same shaft. Later, designs were introduced for use with independent fans, and on integral-fan type designs, scroll housings were substituted for the former cylindrical housings, as a means of obtaining higher fan efficiency and capacity and more stable operating characteristics. Further fan improvements consisted in provision of (1) separately driven shafts for the forced-draft and the induced-draft fans where desirable for obtaining better draft balance, and (2) a more practical construction for adjustment of fan blades and for replacement of any which became eroded from abrasive fly ash and the location of bearings external to the preheater and fan structure.

The various illustrations show the detail of construction. Fig. 3 shows a type with integral fans, Fig. 4, a small vertical-flow preheater for independent fans and Fig. 5, a large vertical-flow type for independent fans.

Michigan Saves in State Institutions

How sizeable direct savings to the taxpayers of the State can be effected by close scrutiny of operating costs is shown in the recent report of B. J. Abbott, Secretary of the State Administrative Board of Michigan, concerning heating expenses at state institutions. The report notes a saving of $60,500.00 in fuel and power costs for twenty-two institutions for the calendar year ending December 31, 1933 as compared with the corresponding period of 1932.

Savings in the use of coal accounted for $36,000.00 and savings in power costs and fuel oil accounted for the balance of $24,500.00.

These direct savings were made despite a 45 per cent increase in patients at the Ypsilanti State Hospital since July 1, 1932, the opening of a new receiving hospital at Newberry, in October 1933, with the incident increase of 25 per cent in the space to be heated, the opening of a new receiving hospital at Ionia in November 1932, with an increase of 37 per cent in the space to be heated, and despite also the colder weather that has prevailed throughout this winter.

The results were attained largely by stopping steam and hot water leaks, by maintaining even temperatures, by keeping boilers meticulously clean and by competition between the various engineers for enviable records of efficient operation of power plants.

The engineers of the state institutions who were responsible for this record under the insistence of Mr. Abbott and of R. J. Williams, State Efficiency Engineer, held a meeting at Michigan State College late in February and engaged in a practical discussion looking to the bettering of the record already set up.

REVIEW OF NEW BOOKS

Any of the books reviewed on this page may be secured from Combustion Publishing Company, Inc., 200 Madison Ave., New York

Chemical Engineers' Handbook

By Dr. John H. Perry and W. S. Calcott
Assisted by a staff of specialists

A HANDBOOK for the practicing engineer in the field of chemical and process industries. In this field it forms a companion treatise to Marks in the mechanical engineering field. Sixty-three specialists in various branches have contributed to the thirty sections of the book. Mechanical and electrical engineering, such as power generation and application, transmission, fuels, refrigeration, materials of construction, etc., are dealt with to the extent of acquainting the chemical engineer with fundamentals, types and performance to be expected. Conversely, the mechanical engineer will find the book of great assistance in affording a knowledge of processes that utilize the services for which he is responsible.

The book contains 2609 pages, size 5 × 7. Price $7.50.

Vocational Guidance in Engineering Lines

DESPITE the fact that on the average only about 37 per cent of the engineering students who matriculate are graduated, there are still many misfits in the active practice of engineering—men not fitted by temperament nor inclination. The weeding-out process in the university course represents a tremendous waste in educational effort.

This situation, long recognized, results from lack of proper vocational guidance in the preparatory school period. Students usually decide upon an engineering career because of some friend who has or is going to take such a course; because they have read books on engineering accomplishments; or because they imagine themselves mechanically minded from having acquired a liking for certain popular magazines in that field. As a rule, they have no conception of what constitutes engineering in its various branches nor the basic requirements necessary to its successful attainment. Parents and teachers are seldom able to advise intelligently in these matters.

With the thought of assisting in the solution of this problem, the American Association of Engineers about three years ago appointed a committee, of which Dr. J. A. L. Waddell was chairman. This committee enlisted the aid of specialists in practically every branch and subdivision of engineering, and the present book is the result. Each of these specialists tells frankly what constitutes his particular branch, the fundamental training required, and in some instances the remunerative opportunities.

While engineering accomplishment is featured, it is frankly pointed out that "of the hundreds who faithfully devote themselves to the task, only a few are destined to receive any significant reward—in either money or fame." Because of this, it requires the maximum of natural aptitude and of liking for the work, and those who do not possess a thorough ground in mathematics and physics are advised against taking up an engineering course.

The book is unique. It is authoritative and should be carefully read by all high-school students who contemplate engineering as a career. Parents and teachers will find it not only informative but of invaluable assistance in guiding the student and judging his fitness.

This book contains 521 pages, size 6 × 9. Price $2.50.

Book of A.S.T.M. Tentative Standards—1933 Edition

THIS annual publication of the American Society for Testing Materials contains all tentative specifications, methods of test and definitions of terms issued by the Society covering engineering materials and the allied testing field. Although in the trial stage of standardization procedure, these tentative standards, embodying the latest practices, find important application and are widely used in industry.

The 1933 edition of this book contains 223 tentative standards. Of these, 47 are published for the first time, while some 41 were revised in 1933 and are given in their latest approved form.

New tentative standards, which were published in 1933 for the first time, cover the following ferrous and non-ferrous materials: steel for bridges and buildings; mild steel plates; high tensile strength carbon-steel plates; alloy-steel and carbon-steel castings; elliptical springs; lapwelded and seamless steel pipe for high-temperature service; zinc coating on hardware and fastenings; wrought-iron rivets; and magnesium ingot and stick for remelting.

New tentative test methods include the impact testing of metallic materials, short-time high-temperature tension tests, and "creep" tests.

Included in the list of widely used materials covered by revised tentative specifications and test methods are the following: aluminum, aluminum-alloy (Duralumin) and aluminum-manganese alloy sheet and plate; zinc-base alloy die castings; metallic materials for electrical heating; coke (sampling for analysis); calcium chloride; insulated wire and cable.

In addition to all of the A.S.T.M. tentative standards, the 1933 edition of this book gives proposed revisions of standards, which are published tentatively to elicit criticism before final adoption.

The book has a complete subject index, and two tables of contents, one listing the items under the general materials covered, the other in numeric sequences of their serial designation.

This publication contains 1136 pages, size 6 × 9. Price: cloth binding $8.00; heavy paper cover $7.00.

Twelfth Edition of the A.S.H.V.E. Guide

THE A.S.H.V.E. Guide 1934 is just off the press and is ready for distribution. The Technical Data Section of this edition has been enlarged to include newly developed data that are vitally important in meeting the present-day demands of engineers who devote their time to heating, ventilating and air conditioning practice. From the practical experience of members as well as from available research sources useful facts have been gathered and incorporated in the forty-two chapters which have been arranged for convenient reference. An extensive index has been included to aid the reader. The text is prepared for engineers, architects, contractors and students who are designing, operating, specifying, installing and studying systems and apparatus the functions of which are to create comfort and to improve the efficiency of processing.

All of the data in the previous edition have been reviewed, many chapters have been revised and amplified while others have been completely replaced. The new chapters include the Cooling Load and Cooling Methods, Unit Conditions, Radiant and Electric Heating, Humidifying and Dehumidifying Equipment, Steam Heating Systems and Piping. The tables of pipe sizes for steam systems have been presented in more compact and simplified form. Extensive changes will be noted in the chapters on Industrial Air Conditioning, Natural Ventilation, Central Fan Systems, Air Cleaning Equipment, Sound Control, Mechanical Furnace Systems, Radiators and Gravity Convectors, Heating Boilers, Pipe Insulation, Pipe, Fittings and Welding, Definitions and Terms. The remaining chapters were revised in order to bring them up-to-date.

Slight modifications were made in the chapters on Heat Transmission and Air Filtration based on a careful check of the experimental work which produced the basic figures. However, the method of application in practice has been slightly modified in this edition.

The book was prepared under the direction of The Guide Publication Committee consisting of W. L. Fleisher, Chairman, D. S. Boyden, F. E. Giesecke, S. R. Lewis, Perry West and about fifty others cooperated in the preparation, reviewing and edition of the text. Bound in a flexible red cover 6 × 9 in. it contains 862 pages and 56 pages in the membership section. Price $5.

St. Paul Rejects Municipal Power

By a popular referendum vote of 48,526 to 32,226 on March 6, the residents of St. Paul defeated a proposed bond issue of ten million dollars for the construction of a municipal power plant. The proposed plant would have been adequate to have served about 40 per cent of land now served by the Northern States Power Company. The agitation for a municipal plant was the result of failure of the city and the private power company to agree on the terms of a new franchise to replace that which expired last year.

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Air Compressors

A bulletin just released by the Worthington Pump and Machinery Corporation, Harrison, N. J., describes Type VA-2 compressor unit which has been devised especially for use in repair shops. The compressor is mounted on the air storage tank and the whole arrangement is very compact. These compressors are made in eight sizes and for pressures of 150 to 200 lb.

Air Preheaters

A new bulletin No. 933 has been issued by the Air Preheater Corporation, 60 East 42nd Street, New York, illustrating various applications of the Ljungstrom air preheater. It covers both public utility and industrial power plant applications and should interest those concerned with heat recovery problems.

Automatic Combustion Control

Bulletin No. 320, issued by the Denver Fire Clay Company, Denver, Colorado, describes the new D.F.C. Automatic Combustion Control. This control is designed particularly for application to gas-fired boilers operating under natural or induced draft and fired with atmospheric type gas burners. It is a proportioning control in that it maintains a definite relation between the steam output and the fuel input and between the quantities of fuel and air flowing into the furnace.

Boiler Feed Pumps

"Modern Boiler-Feed Pumps" for pressures up to 600 lb is the title of a new bulletin No. 2078 by Ingersoll-Rand Co., describing the Cameron Type NT multi-stage centrifugal pumps. An interesting feature of this pump is the hydraulic balance obtained by placing an equal number of impellers back to back. This results in the elimination of high-pressure stuffing boxes. Of the two stuffing boxes used, one is under second-stage pressure, the other is under suction pressure. The casing is split horizontally, allowing the entire rotor to be removed from the pump without disturbing the bearing adjustment, exposing bearings to dirt or moisture, or disconnecting any part of the piping.

Centrifugal Pumps

"Monobloc" centrifugal pumps of the two-stage type, having steep head-capacity characteristics, and especially adapted to boiler return systems, laundries, chemical process work and refrigeration service are described in a bulletin by the Worthington Pump and Machinery Corporation, Harrison, New Jersey.

Combustion Control Equipment

A series of new bulletins has recently been issued by the Hagan Corporation, Pittsburgh, describing the construction and operation of their various units of automatic combustion control equipment. These units have been redesigned and improved during the past two years and these bulletins explain the changes that have been made. The items covered by the separate bulletins are the master regulator, balanced float regulator, impulse amplification and remote control system, master sender, receiving regulator, compensating relay, control panels and type C float sender.

Cycloidal Rotary Pumps

Bulletin 60-B10, descriptive of Cycloidal rotary pumps, has just been issued by the Roots-Connersville Blower Corporation of Connersville, Ind. These pumps are built on the two-impeller principle, with two and three-lobe impellers, depending upon the type of service to which they are applied. Cycloidal rotary pumps are built for heavy duty service, including the handling of viscous liquids, or for producing vacuums up to 26 in. of mercury (or approaching the barometer under special conditions), handling air and liquids simultaneously.

Special attention is devoted to illustrating and describing the Type 'R' pump, which is a comparatively recent development of the cycloidal design. In this pump, the cylinder is made integral with the base, with the inlet at either side to suit individual plant piping conditions. Discharge is at the top. Large diameter shafts are supported on four anti-friction bearings. Timing gears are machined from forged steel blanks, and heat-treated. Bearings and gears are protected from contact with the fluid being handled by improved stuffing boxes.

Flexible Couplings

A very complete 72-page catalog on flexible couplings has recently been issued by the Poole Foundry & Machine Company of Baltimore. A number of unusual designs, heretofore not listed, are described in addition to the more widely known types and each is accompanied by full dimensional tables and other data. Information on applications is also included.

Metallic Packing

Metallic packing for use in connection with steam, air, gas, gaseous ammonia and carbon dioxide equipment is shown in a new 36-page catalog of the American Metallic Packing Company of Pittsburgh, Pennsylvania. Special engineering service is offered where unusual conditions require individual design and emphasis is placed on packing for high-pressure compressors, up to 1200 lb and similar installations. Numerous drawings illustrate the different styles of packing rings available in a wide range of diameters and the data is so simplified as to be readily understood.

New Line of Compressors

A complete new line of direct-connected gas engine driven compressors, designated as "Type XVG" is described in a new catalog recently issued by Ingersoll-Rand Company, 11 Broadway, New York. The units consist of vertical four cycle multi-cylinder "V" type gas engines with direct-connected standard I-R horizontal compressor cylinders. This arrangement is said to result in remarkably well balanced smooth running machines, the moderate weight of which permits shipping from the factory completely assembled units. Light, strong reciprocating parts, large bearings, low piston speeds and conservative ratings, insure low maintenance costs and long life.

Refractory Cement

A bulletin by the Atlantic Refractories Company, Boston, describes "Blackote," a silicon-carbide refractory cement suitable for temperatures up to 3500 F. This cement is used for laying up and face coating brickwork, arches and baffles in oil, pulverized-coal or stoker-fired furnaces, or for protecting waterwall blocks and refacing brickwork that has started to spall and corrode. It is also used in industrial furnaces. The bulletin gives its various characteristics and describes its application.

Self-Cleaning Bar Screen

Bulletin No. 571 has been issued by The Jeffrey Manufacturing Company of Columbus, Ohio, describing a new self-cleaning bar screen, which is automatic in operation. One of the features of this new screen is that the scraper mechanism enters the water behind the accumulated refuse, drags horizontally for approximately two feet and then ascends, thus collecting refuse that may settle on the floor as well as on the screen.

Traps

A new twenty page catalog entitled "The Solution of Your Condensation Problem" is now being distributed by the Nason Manufacturing Company, New York, manufacturers of steam traps and steam specialties. The catalog describes and illustrates a complete line of steam traps: bucket, ball float return, etc., for all purposes.

NOTICE

Manufacturers are requested to send copies of their new catalog and bulletins for review on this page. Address copies of your new literature to

COMBUSTION
200 Madison Ave., New York

ADVERTISERS
in this issue

EQUIPMENT SALES
Boiler, Stoker, Pulverized Fuel

As reported by equipment manufacturers of the Department of Commerce, Bureau of the Census.

Boiler Sales

Orders for 45 water-tube and h.r.t. boilers were placed in January

	Number	Square Feet
January, 1934	45	130,302
January, 1933	34	136,509

NEW ORDERS, BY KIND, PLACED IN JANUARY, 1933–1934

Kind	January, 1933 Number	January, 1933 Square Feet	January, 1934 Number	January, 1934 Square Feet
Stationary:				
Water tube	24	122,324	22	96,695
Horizontal return tubular	10	14,185	23	33,607
	34	136,509	45	130,302

Mechanical Stoker Sales

Orders for 123 stokers, Class 4,* totaling 19,200 hp. were placed in January by 60 manufacturers.

	Installed under Fire-tube Boilers No.	Fire-tube Boilers Horsepower	Water-tube Boilers No.	Water-tube Boilers Horsepower
January, 1934	100	10,775	23	8,425
January, 1933	55	7,975	13	4,780

* Capacity over 300 lb of coal per hr.

Pulverized Fuel Equipment Sales

No orders for pulverizers reported in January

STORAGE SYSTEM

	Pulverizers: Total number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb coal per hour for contract	Water-tube Boilers: Number	Total sq ft steam-generating surface	Total lb steam per hour equivalent
January, 1934	..	..	..	....	..	....	......
January, 1933	..	..	..	....	..	....	......

DIRECT FIRED OR UNIT SYSTEM

	Pulverizers				Water-tube Boilers		
January, 1934	..	..	..	......	..	......	....
January, 1933	10	10	..	72,600	5	64,434	655,000
					Fire-tube Boilers		
January, 1934	..	..	..	....	..	....	......
January, 1933	1	..	1	1,250	1	1,500	10,300